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IOWA

GEOLOGICAL SURVEY

96647

VOLUME X

ANNUAL REPORT, 1899

WITH

ACCOMPANYING PAPERS

SAMUEL CALVIN, A. M., PH. D., STATE GEOLOGIST
H. F. BAIN, ASSISTANT STATE GEOLOGIST

DES MOINES:
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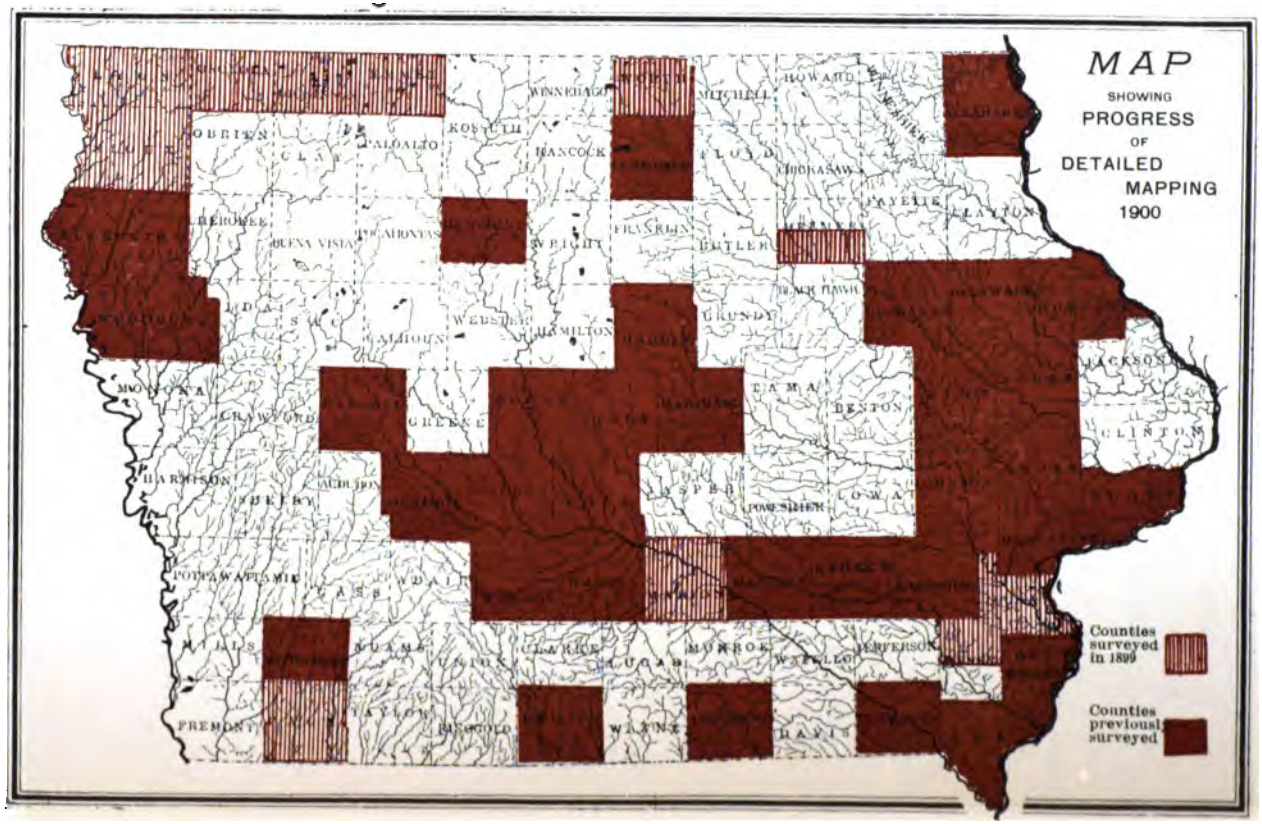
ADMINISTRATIVE REPORTS.


MAP
SHOWING
PROGRESS
OF
DETAILED
MAPPING
1900
Counties surveyed in 1899
Counties previously surveyed
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
WINNEBAGO
MITCHELL
HOWARD
HANCOCK
FLOYD
CHICKASAW
FAYETTE
CLAYTON
CHEROKEE
BUENA VISTA
POCAHONTAS
WRIGHT
FRANKLIN
BUTLER
BLACK HAWK
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
GRUNDY
MONONA
CRAWFORD
GREENE
TAMA
BENTON
JACKSON
CLINTON
HARRISON
SHELBY
AUDUBON
JASPER
POWESHIEK
IOWA
POTTAWATTAMIE
CASS
ADAIR
MILLS
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
FREMONT
TAYLOR
RINGGOLD
WAYNE
DAVIS

EIGHTH ANNUAL

REPORT OF THE STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1899.

To Governor Leslie M. Shaw and Members of the Geological Board:

GENTLEMEN—I have the honor of submitting to you, in accordance with law, my report of the operations of the Iowa Geological Survey for the year 1899. The energies of the Survey have been devoted to carrying out the plans approved by you at the beginning of the working season, and it is hoped that in the extent and quality of the work accomplished all your expectations have been fully met. The corps of investigators engaged upon the work of the Survey during the past year has been somewhat larger than heretofore. In addition to the State Geologist, the Assistant State Geologist and the Secretary, the force has included Dr. S. W. Beyer, Dr. J. B. Weems and Mr. Ira Williams of the State College at Ames; Prof. W. H. Norton of Cornell College, Mount Vernon; Dr. T. H. Macbride of the University of Iowa, Iowa City; Prof. J. A. Udden of Augustana College, Rock Island; Prof. Benj. L. Miller of Penn College, Oskaloosa; Mr. Frank A. Wilder of the West Des Moines High School; Prof. T. E. Savage of Western College, Toledo; and Mr. H. R. Mosnat of Belle Plaine. In addition Mr. Stuart Weller of the University of Chicago spent a short time at Burlington, and Prof. A. V. Sims of the University has kindly undertaken some special tests. Mr. Frank Tate and Miss Charlotte King have each spent some time in preparing illustrations for the reports.

During the year the Survey has directed its attention chiefly to the work of mapping the various unsurveyed counties and to the preparation of reports on the physiography, geology, and resources of the areas so mapped. In all eight counties have been mapped this season, and partial mapping has been done in two more. Revision work was carried on in three counties which had been essentially completed during the preceding season.

In the following table there is given a list of the counties in which mapping has been done. The names of those completed within the year are set in italics, and the names of two, begun during the year, but not yet completed, are set in capitals. In all nearly 24,000 square miles have been so far surveyed, an area which embraces almost half the state. The remaining area will require less work than the portion of the state already surveyed. The location of the several counties surveyed and the distribution of the areal work are shown on the accompanying map (Plate I).

COUNTIES SURVEYED AND MAPPED.

	AREA SQ. MILES.		AREA SQ. MILES.
Allamakee	658	Linn	720
Appanoose	576	*Louisa*	407
Boone	576	*Lyon*	587
BREMER	432	Madison	576
Buchanan	576	*Marion*	576
Carroll	576	Marshall	576
Cedar	576	Montgomery	432
Cerro Gordo	576	Muscatine	437
Dallas	588	*Osceola*	400
Decatur	576	*Page*	557
Delaware	576	Plymouth	860
Des Moines	415	Polk	585
Dickinson	404	Scott	455
Dubuque	601	*Sioux*	769
Guthrie	593	Story	576
Hardin	576	Van Buren	484
HENRY	433	Warren	569
Humboldt	432	Washington	655
Johnson	618	Woodbury	873
Jones	576	*Worth*	402
Keokuk	576		
Lee	512	Total	23,903

At the close of the last field season some 18,936 square miles had been mapped. It was found impossible, however, to prepare reports on Cedar, Hardin, and Dubuque counties in time for publication in volume IX, and they were accordingly left over for the present volume. This gave an opportunity for a certain amount of revision both in the field and the office, and the reports have gained in value as a result of the delay. This delay has been especially advantageous in the case of Dubuque county, as it will now be possible to incorporate in the report the important results of the mining development of the past season. It also makes it possible to use, as a base map, the topographic sheets covering this area, prepared by the United States Geological Survey. Indeed it was mainly to render this possible that the work was held over, for without a good topographic base map, the detailed geological mapping of a region as rough and broken as the Driftless Area would be altogether impossible. The expense involved, however, in making such a map is far beyond the resources of the Iowa Survey.

The Maquoketa, Anamosa, Elkader and Lancaster sheets of the United States Survey have been but recently completed and have not yet been published. Through the kindness of the director, Prof. Charles D. Walcott, photographic copies of these sheets have been furnished the Iowa Survey for field use and for publication. From them Messrs. Hoen & Co., of Baltimore, are now preparing the base map which will be used in the Dubuque county report. The co-operation of the United States Survey in this matter is very much appreciated and the map will add very greatly to the value of the report.

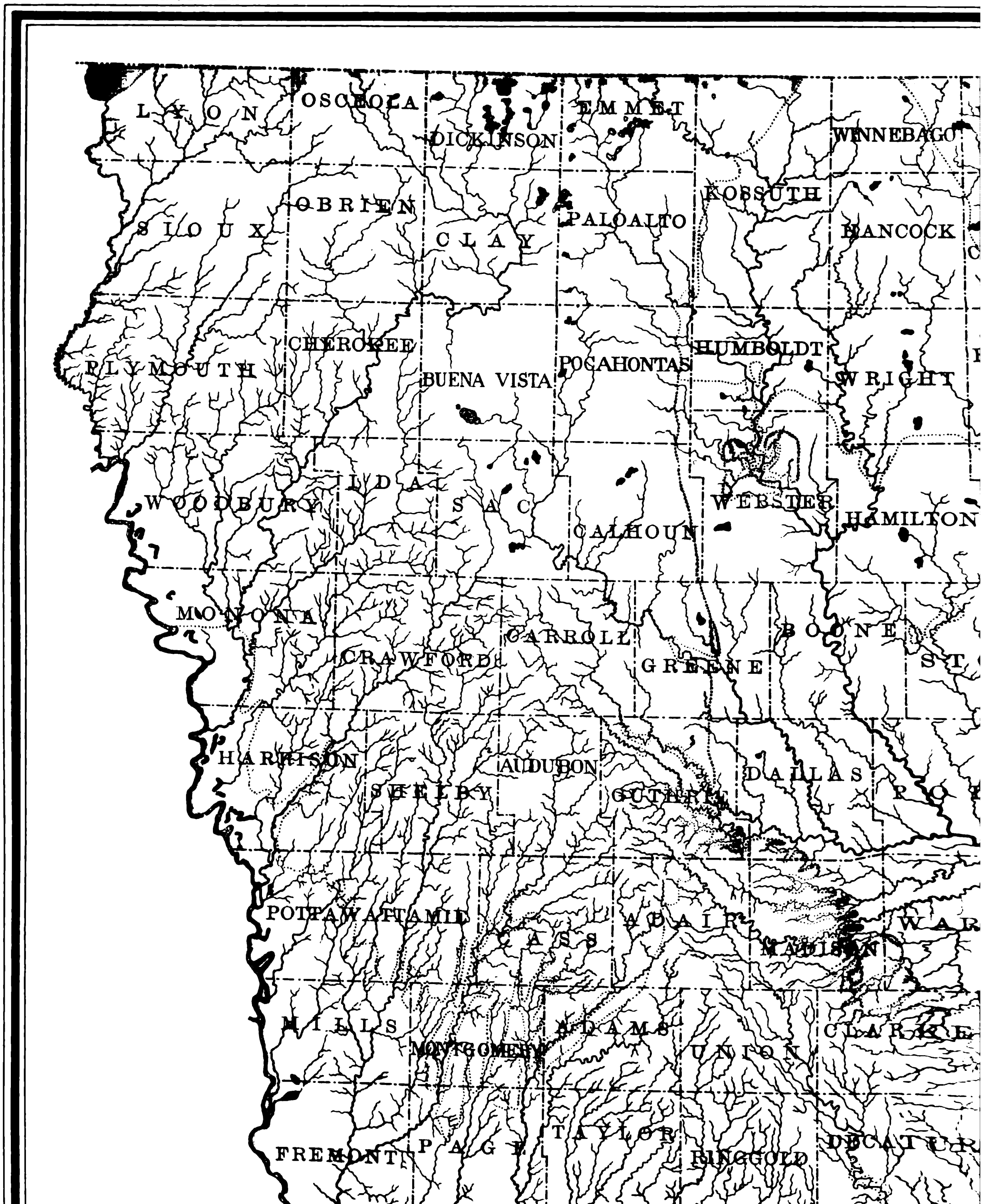
The work in Dubuque county was undertaken jointly by the Director and the Assistant State Geologist. I took up the stratigraphical and general geological problems, while the assistant investigated the economic phases of the subject. Accordingly Mr. Bain has devoted much time to the study of the problems presented in the mining areas of the county, and particularly to watching the development of the zinc mines

which, under the stimulus of his suggestions, are now opening up with prospects of greatly increased success. Further details will be found in his administrative report.

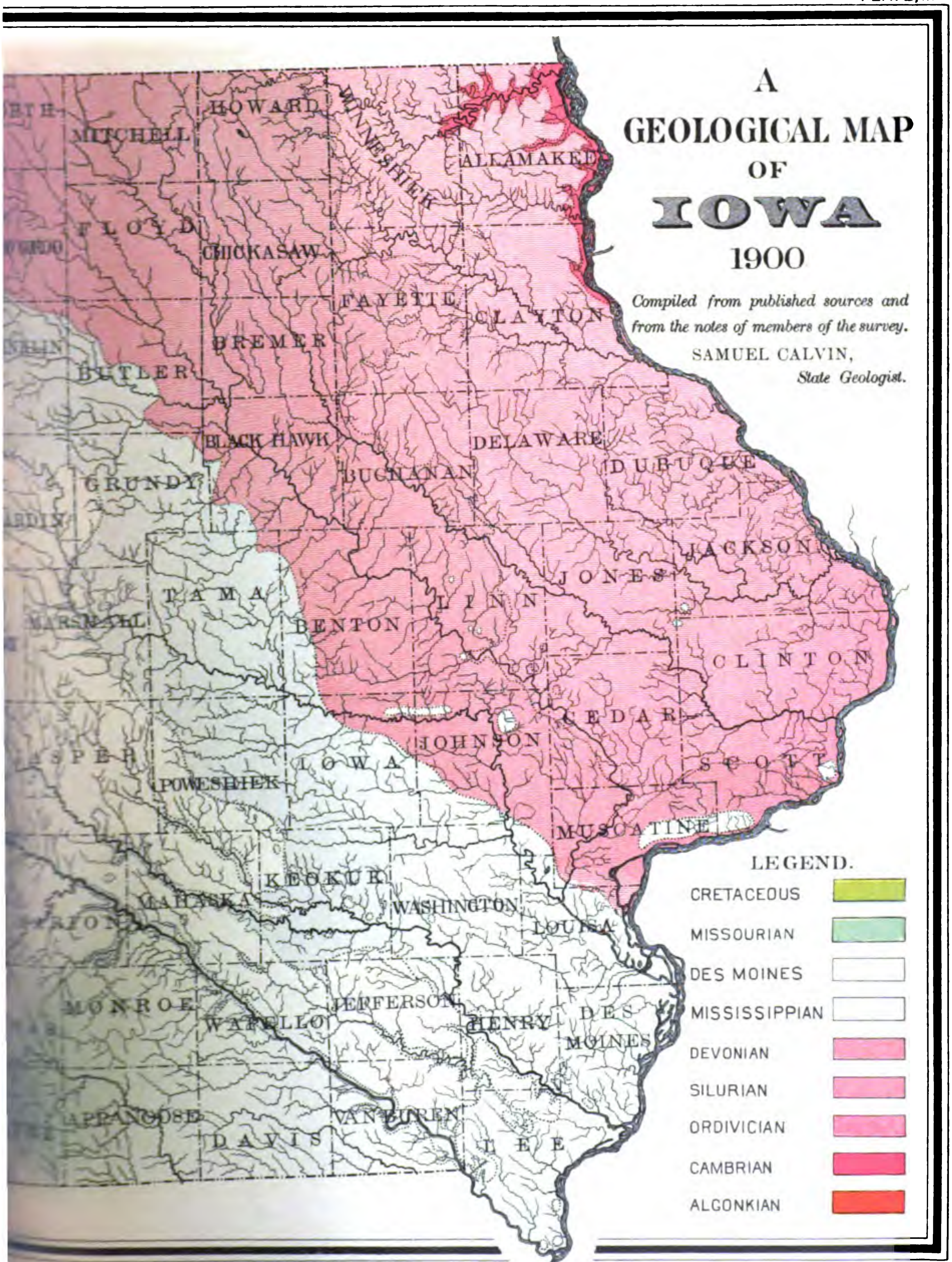
In Cedar county the work begun by Professor Norton last year was carried to completion. Cedar county contains some of the largest and most important quarries in the state and is the seat of an important lime industry. The stone industry of this county in 1898 amounted to $113,502, and Professor Norton's work confirms the fact that there are large opportunities for expansion. The clay interests of the region are worthy of further development.

In Hardin county Dr. Beyer has devoted considerable attention to the clay interests. There is a very wide variety of clays to be found in the county and the quantity present is all that could be desired. While there are now several plants in operation the clay industry has not been developed to anything like the extent which the character of the material and the commanding position of the county should render possible. The stone industry may also be expected to develop largely. These and the other mineral resources of the region are fittingly discussed in the report upon the county now in preparation.

The new work taken up this year was widely scattered and served to close some of the important gaps in our earlier mapping. Much attention was paid to the western portion of the state, the mapping in the northwest being extended to cover Lyon, Sioux, Osceola and Dickinson counties. The work in the two counties first named was done by Mr. Frank Wilder with the assistance of Mr. Bain. Preparatory to it a general reconnoissance trip was made through several of the adjoining counties. Mr. Wilder's studies have been of great importance in bringing out the fact that the Hawarden beds, heretofore referred to the Ft. Pierre, really belong to the Benton shales and accordingly the limestones and chalk of the Inoceramus beds, as developed in Iowa, are not to be correlated with the Niobrara farther west. They represent instead that


LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
OBRIEN
SIOUX
CLAY
PALO ALTO
KOSSUTH
HANCOCK
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POTTAWATTAMIE
CASS
ADAIR
MADISON
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR

PLATE, II.



A
GEOLOGICAL MAP
OF
IOWA
1900
Compiled from published sources and from the notes of members of the survey.
SAMUEL CALVIN,
State Geologist.
LEGEND.
CRETACEOUS
MISSOURIAN
DES MOINES
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDIVICIAN
CAMBRIAN
ALGONKIAN
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
FLOYD
CHICKASAW
FAYETTE
CLAYTON
BREMER
BUTLER
BLACK HAWK
DELAWARE
DUBUQUE
BUCHANAN
GRUNDY
JACKSON
JONES
TAMA
BENTON
LINN
CLINTON
CEDAR
JOHNSON
SCOTT
IOWA
POWESHIEK
MUSCATINE
KEOKUK
MAHASKA
WASHINGTON
LOUISA
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
APPANOOSE
DAVIS
VAN BUREN
LEE

portion of the Fort Benton sub-stage exposed in the "Oyster Shell Rim" of the Black Hills. Mr. Wilder has also shed much light upon the vexed question of the age of the drift of the northwestern part of the state. His conclusions, while differing somewhat from those previously held by the Survey, are founded on careful study and seem worthy of every confidence. Probably a final opinion on the subject can not be rendered until more of the region shall have been investigated.

Mr. Wilder shows in his report upon the two counties that the Dakota sandstone, which in South Dakota is such a common source of artesian water, is an important aquifer throughout the region, though not yielding flowing wells. His report is now in the final stages of preparation and will doubtless be ready for publication in this volume.

In Osceola and Dickinson counties Professor Macbride has extended his studies which he made the year before in Humboldt county. The Osceola-Dickinson area is one of very exceptional interest. Here, connected with the drift, are geological problems of highest import. Morainic knobs and kames and undrained marshes, set in level expanses of beautiful prairie land, appear at first sight to be distributed lawlessly over the region, but the difficulties of their peculiar distribution yield to the careful questionings of the trained investigator, and at length something like order is evolved from the seeming confusion. They have all been developed in accordance with definite laws governing the transportation and deposition of material in connection with the movements of glaciers. In this region, too, are found the principal lakes of Iowa, charming sheets of water, surrounded usually by swelling knobs of the glacial moraine which in places is forested and in places grass-covered to the water's edge. Lake and forest and grassy slope unite to form a landscape of rare natural beauty but seldom equaled. The genesis of the lake basins, not less than the genesis of the other topographic features of the region, has long been an attractive problem to

the man of science; in the opportunities for rest, for recreation, for the quiet, joyful stimulation and exercise of the æsthetic sense, which the lakes and their delightful surroundings afford, the general public has found the same region one of great attractiveness. Professor Macbride tells the interesting history of the region in a manner at once clear, comprehensive, and comprehensible; and it is to be hoped that his suggestions for preserving it with what is left of its natural beauty, and converting it into a resort where Iowa's citizens may, for all time, have an opportunity to come in touch with Nature at her best, where physical health and mental tone can be restored to all who are worn and weary from over-exercise of hand or brain, will receive the attention which they deserve.

In the southwest the work left unfinished by the death of Mr. Lonsdale has been resumed. After some field conferences with members of the Survey corps, and after revising and completing the work in Dubuque, I began the survey of Page county. The thickness and succession of the strata composing the Upper Coal Measures in southwestern Iowa, and the relations of these strata to the published sections of Nebraska and Missouri on the one hand, and to those of Iowa on the other, have long been recognized as questions which deserved thorough investigation. As a result of the work in Page county it is shown that, compared with the basal portion of the Upper Coal Measures, Missourian stage,—as developed in Madison county for example,—the deposits here contain less limestone and relatively more of shale and shaly sandstone. This means that shallow-water and marginal deposits are more abundant, and that the conditions for the accumulation and preservation of coal were more favorable in Page county than in regions where the earlier portions of the Missourian stage are exposed. Limestone ledges are here comparatively thin and far apart, while clay deposits reach an unusual development. It is also shown that there are two distinct coal horizons separated by about 130 feet of strata, embracing a few feet of limestone and nearly 120 feet of shales and shaly sandstones.

The rather indefinite line along which the eastern loess and the Missouri river loess meet is found near the western border of Page county, lying chiefly, however, in Fremont. The drift of Page county is, in places, very thick, and it has suffered much more than the average amount of erosion seen in areas south of the Iowan border. The principal stream valleys average nearly 200 feet in depth, cut mostly in the drift; and the sides of the valleys, back to the divides, have been carved into an intricate and branching series of ravines and ridges which cover the whole surface, leaving no part of it in the condition of an uninvaded plain or plateau. The soils are unsurpassed anywhere for the production of corn and other field crops. The coal seams are rather thin, but they are remarkably persistent, and the mining industry is capable of greater development than it has yet attained. With better knowledge of the position of the coal seams the work of prospecting can be carried on more intelligently, and the top works can be located so as to operate the mines with a minimum of expense.

In the central portion of the state Prof. Benj. L. Miller, who has had considerable experience in geological work in connection with the University Geological Survey of Kansas, undertook the mapping of Marion county. His map and report are now in hand and show that the work has been executed with great care. Marion county is located near the central part of the coal field, and while mining is not now as extensive as in certain of the neighboring counties, the coal measures appear particularly rich. With improved railway facilities in the southern portion of the county it may confidently be predicted that valuable mines will be opened up. It is to be expected that Professor Miller's report will prove of material assistance in bringing this about.

Early in the season Professor Udden took up the work in Louisa county, extending over it the survey which he had, the previous season, made in Muscatine county. To the south he connected with Dr. Keyes' mapping of Des Moines county, on the north with my own in Johnson county, and on the west

with that of Mr. Bain in Washington county and Professor Savage, who was working in Henry county. In Louisa county, aside from many interesting problems of general geological interest, Professor Udden made a careful study of the gas field near Letts, which has for some years, yielded heat and light to a number of the citizens. He made a careful test of the pressure in wells and studies of the source of the gas. While his results are discouraging to those who expect high pressure gas to be found by deep drilling, they serve to show that the field may be of some considerable local importance and that the supply is steadier than is usual in the case of drift supplied wells.

In Henry county, Professor Savage devoted some time to a study of the formations present. He is now engaged in studying the fossils and other specimens collected, and with another field season he may be expected to complete the survey of the county.

After he had finished the survey of Cedar county, Professor Norton was transferred to Bremer, where he spent the final weeks of the field season. In Bremer he has an opportunity to carry farther his studies of the Silurian and Devonian, which his previous work in Linn, Scott and Cedar counties has done so much to clear up. At Waverly, Professor Norton was called upon to advise as to the necessity of drilling deeper the well which supplies the city with water. After a careful investigation of the subject he demonstrated that deeper drilling was inadvisable, and a test showing sufficient supply of water present, the purpose was thereupon given up. This made a saving to the city estimated at $6,000 besides preserving the water supply from mixture with the more highly mineralized and less desirable waters which are found at lower horizons.

In Worth county, Mr. Ira Williams, under the immediate direction of Dr. Beyer, made a detailed survey. Worth lies immediately north of Cerro Gordo county and the same formations are exposed over both. The work in Cerro Gordo was completed in 1897 and Mr. Williams has now extended it to

cover the neighboring county. His report, which is now in hand, shows that his work has been done with great care and it will form an acceptable addition to the series of reports already issued.

In addition to the areal work, there has been an increasing amount of subject work taken up by the Survey. It is important that the people of a given locality should have a report upon the resources of the region. It is, however, equally important that the man who wishes to know something of the coal, building stones, clays, cement materials, iron ores, lead and zinc, artesian waters, or other resources of the state without respect to special areas, should have the best information obtainable made available to him in compact form. If it is necessary to run through a whole series of county reports a stranger is apt to become confused and lose the proper perspective. As a matter of fact the Survey has more calls for information from intending investors, relative to particular subjects than to particular regions, and accordingly an effort is being made to investigate as completely as may be the whole of these particular subjects. With this in view a report upon the coal deposits was among the first prepared by the Survey. Later, reports upon gypsum, artesian wells, lead and zinc and certain of the phases of the building stone industry were issued. Some of these, notably those relating to the building stones and artesian wells, will require further elaboration as a consequence of new development. After the work in the various counties shall have been completed it will be a relatively easy matter to furnish a full and accurate report upon these various subjects. Such reports must necessarily include much of a general nature not appropriate in the county reports. The artesian well report will, it is expected, be from time to time supplemented by notes upon the new wells. Professor Norton is now collecting and collating the material for the first of these supplements. The report upon Dubuque county will serve as an important supplement to Mr. Leonard's paper on the lead and zinc. There are no imme-

diate plans for a special report upon the building stones, though a considerable amount of data for such a report has been collected. Within the year an abstract of this was furnished to Mr. Whittle of Boston, who is preparing a general report upon the building stones of the United States. By this means Iowa stones are assured a proper representation.

The most important move during the year in the matter of subject work has been the organization of a joint commission to investigate the clay resources of the state. In this work the Geological Survey has taken an active part, and is glad to have had the privilege of co-operation with such bodies as the Iowa Brick and Tile Makers' Association, Iowa Engineering Society, the State College, and the State University. The organization and purpose of the commission referred to is set forth in the following circular issued by them and the work done since its organization is detailed in Dr. Beyer's report.

In 1898, eighty-seven out of the ninety-nine counties of Iowa produced some form of clay goods. In all, over $2,000,000 worth of brick, tile, etc., were manufactured and sold, and 349 establishments were reported. The increase in output of recent years is very marked. The great paving brick industry, with its output valued at from a quarter to a half a million dollars, has grown up within the last few years. In 1897 Iowa ranked third in the production of paving brick, and it is now the most important state west of the Mississippi in that industry. Important, however, as the clay industry has become, it still lags behind the opportunity. There is cheap and abundant fuel. Almost every geological formation in the state yields some clay suitable for manufacture. There are large areas underlain by the clays of the Cretaceous, which yield such superior product in New Jersey and other Atlantic states, as well as at Golden, Colo., and other points in the west. The coal measures, the great storehouse from which Pennsylvania, Ohio and Illinois draw their clay, cover nearly 20,000 square miles in Iowa. They afford a wide variety and a great abundance of clay. The loess, an incomparable material for ease of working and cheap production of standard builders, covers all or parts of sixty-nine counties. Lumber is largely imported, stone is not much in use, the cities and towns are now putting up the second generation of buildings, and everything conspires to favor a good local market. To the north and west is a wide area devoid of fuel, and largely wanting in suitable clays, which must ultimately be good trade territory.

In spite of these favorable conditions, Iowa has for years imported large quantities of clay goods. The bulk of the pottery used in the state, both fine and common, is manufactured elsewhere; the bulk of the fire brick is also shipped in. Large quantities of sewer pipe, paving brick, terra-cotta and fancy building brick, come from outside its borders. This can only come from lack of appreciation of the importance of the local clays, or lack of ability to develop them.

When, in 1892, the Geological Survey was organized, it was seen that the clays would be one of the most important subjects for investigation, and provision was made for their study. Mr. E. H. Lonsdale, at that time engaged in work for the Missouri Geological Survey, was placed in charge of the work, and devoted his attention to it in the years 1893 and 1894. His removal from the state, and subsequent death, left the work unfinished, though many valuable notes had been collected. In the need of pushing the areal work it was found impossible to detail anyone else to this particular subject. In the meantime the work of the county surveyors continued to show the great extent of undeveloped resources, and notes on the extent and occurrence of the various clay beds were continually collected. It was impossible, however, to take up the study of the clays themselves, for want of either proper laboratory equipment or the funds to purchase necessary instruments and supplies.

In the meantime the paving brick industry became more and more important. The city engineers of the state, and other members of the Iowa Engineering Society, had the problems relating to brick paving brought to their attention in the course of their professional work, and at their annual meetings a number of important papers were read bearing on different phases of the subject. The engineers, however, worked almost altogether with the finished material. They could determine the faults of the latter, but had little opportunity to study the causes back of these faults, and none to apply a corrective. It was also found that there was strong need of standard specifications and standard methods of testing. The tests formulated by the National Brick-makers' Association were found to be open to some doubt. The exhaustive work of Marston showed that the cross-breaking test was probably much more reliable than the national committee had rated it. Boynton, after a careful series of tests, found it better to use scrap-iron in the rattler. There was grave question, in particular, whether the National Brick-makers' Association did not rate the soft brick unduly high.

When these matters were brought to the attention of the society at its meeting in 1893, a committee was appointed to consider the entire subject of paving brick and paving brick tests, with a view to some common understanding as to the qualities desirable and attainable. This committee consists of Messrs. A. Marston, of Ames; C. R. Allen, of Ottumwa; C. P. Chase, of Clinton; C. S. Magowan, of Iowa City, and E. P. Boynton, of Cedar Rapids.

The brickmakers of the state have been vitally interested in the development of the paving industry and of the clay industries in general. Individually, they have experimented and have employed experts to study their clays and products. Large sums of money have been spent in an effort to determine the needs and proper methods of manufacture of pavers. So long, however, as there was neither a standard of quality nor any uniform method of testing, the results were uneven. A manufacturer might spend money, time and labor to turn out a brick which he knew would wear well and then have it rejected by some test of which he had never before heard. The necessity for a common understanding became apparent. This matter of paving brick is simply one in which there was this necessity. There were other problems which quite as much needed careful and systematic investigation by experts.

The notable work done in Ohio by the School of Ceramics at the Ohio State University, under the aggressive direction of Prof. Edward Orton, Jr., has attracted much attention, and in Iowa there has been a growing conviction among those interested that a similar institution was badly needed. At Columbus they

have a complete plant for testing clays on a working scale. Soft and stiff mud machines, dry presses, repress, driers and kilns are all in use. Most of the machinery was donated by the manufacturers in the interest of better clay working.

At the winter meeting of the Iowa Brick and Tile-makers' Association, at Sioux City, resolutions were passed commending the work of the Geological Survey and urging the advisability of a fuller investigation of the clays of the state. A committee consisting of Messrs. J. H. Charles, of Sioux City; D. W. Townsend, of Cherokee, and J. B. McHose, of Boone, to which has later been added Mr. C. B. Platt, of Van Meter, was appointed to agitate the matter and, if possible, secure action.

At the Iowa State College of Agriculture and Mechanic Arts, located at Ames, tests of paving brick have been carried on quite extensively, and Professor Marston and his associates were planning to carry on the work the coming year. At the State University, Professors Sims and Magowan were also planning to take up the work. Under the circumstances it was thought that the time for united effort had arrived and a call was issued for a meeting at Ames, June 14th, Representatives of the Engineering Society, Brick-makers' Association, Geological Survey and State University accordingly met with the professors of the engineering department of the college, and a joint commission was organized with Prof. A. Marston, of the State college, as chairman and H. F. Bain, of the Geological Survey, secretary. The visitors were welcomed by President Beardshear, after which there was a general discussion of subjects and methods and a plan of work was adopted.

It was decided as a first step to make a careful study of paving brick with a view to the preparation of a report on the methods of manufacture, the formulation of a series of tests, the adoption of uniform specifications and the collection of data as to methods of laying pavements, its cost and life. The latter portion of the work was placed in the hands of the sub-committee of engineers, who were requested to prepare blanks for the collection of this data. The Geological Survey agreed to detail Dr. S. W. Beyer to visit the various plants in Iowa and study their method of manufacture, carrying on temperature, shrinkage, drying and other tests, and collecting samples for farther laboratory studies. Chemical analyses of the clays are to be made by Dr. J. B. Weems, of the college. Cross-breaking, rattler and absorption tests of the brick are to be made in duplicate at the college and State University, and tensile strength and other physical tests of the clays are to be carried on at the same time. The manufacturers are furnishing the material for these tests and bearing a portion of the expense. It is expected that when complete they will yield very important information and will be of material aid in developing the paving brick industry.

It is hoped that this work will prepare the way to the opening of a complete clay-testing laboratory at Ames. At present the college has no room to spare for the work, nor sufficient available funds to carry it on. It is expected that the work on paving brick will be of sufficient practical importance to induce the authorities to provide the necessary funds for further work.

Before adjournment the following resolutions were adopted:

WHEREAS, The clay resources of Iowa have been shown by the Geological Survey to be vast and varied; and,

WHEREAS, These resources are as yet largely undeveloped; therefore, be it

Resolved, That the plan of investigation here outlined is heartily indorsed and the co-operation of the machine manufacturers, brick-makers, and all others interested is urged. Furthermore, be it

Resolved, That the state be urged to establish at Ames a complete laboratory for the testing of clays and clay products.

The progress of the work is set forth in Dr. Beyer's administrative report, which is appended. The materials collected for testing are now assembled at Ames and Iowa City, and as soon as the crowded condition of the buildings at the former place will permit, a building will be set aside for a special clay laboratory.

Perhaps the most important change in the local mining situation within the year has been the opening of the iron deposits near Waukon. That iron ore occurred here, as at other points in Allamakee, Dubuque and Delaware counties, has long been known. Mr. Ellison Orr described the Iron Hill deposit in the first volume of the American Geologist, and it together with two other beds were located and described in the report on Allamakee county appearing in our volume IV. More than twenty years ago an attempt was made to develop the ore. A number of test pits and drill holes were put down to determine its extent, and numerous analyses were made by Professor Fischer of Milwaukee. His analyses, quoted from the printed prospectus of the development company, gave the following results.

FISCHER'S ANALYSES OF WAUKON ORE.

	BLACK ORE.	YELLOW ORE.	AVERAGE ORE.
Iron oxide	.....	.....	56.76
Metallic iron	58.54	54.79	.....
Silica	4.00	5.12	11.02
Water	.....	11.92	11.92
Phosphoric acid	.....	.13	.30
Lime	.....	.70	.70
Magnesia	.....	.....	tr.
Alumina	.....	.....	tr.
Manganese	.....	.....	tr.

Unfortunately, however, the conditions were not ripe for the development of the deposits, for it is the industrial conditions prevailing at any given time, as much as the characteristics of the ore itself, which fix its value.

The present demand for iron ore has attracted attention to the Iowa deposits, and an effort is now being made, with good chances of success, to develop the Iron Hill beds. Through a misprint it develops that the analyses published some time since by the Survey placed the phosphorus entirely too high; an unfortunate error only recently discovered. The decimal was wrongly placed and the correct analyses should read:

	NO. 275.	NO. 278.	NO. 299.
Iron	54.32	66.92	58.68
Sulphur	.....	.47	......
Phosphorus	.13	.503	.115

This is substantiated by the following new analyses made by Professor Weems from samples taken this fall by Mr. Bain, as well as the average results of some fourteen analyses made by various chemists for Mr. Nehrhood, the lessee of the mine, which place the phosphorus at .13 per cent.

WAUKON IRON.

J. B. WEEMS, ANALYST.

Water and loss on ignition	12.34
Silica and insoluble	9.08
Iron oxide Fe_2O_3	68.40
Alumina Al_2O_3	6.08
Manganese oxide MnO	.90
Phosphorous pentoxide P_2O_5	.41
Sulphur	.91
Sulphur trioxide SO_3	.40
Undetermined	1.48
Total	100.00
Metallic iron	47.88
Phosphorus	.18
Total sulphur	1.07

The importance of the Waukon ore is found in the fact of the cheapness with which it can be mined, and its fair quality. The ore is a surface deposit, covered with only very light stripping, and when a switch shall have been run to the mine it can be loaded at a very low price per ton. While it is not so high in metallic iron as the red hematites of the Lake ranges it is high for limonite and is exceptionally low in sulphur. The ore is open and porous, so that it is readily smelted. At

present it is being shipped to Milwaukee and used in furnace mixtures, but if the fuel problem can be solved it is not impossible that the region may see some local smelting.

In connection with the activity in iron mining it is interesting to note that the coal mines of the state have had a year of unusual and welcome prosperity. Several new and important mines have been opened, the Whitebreast mine in Monroe county being one of the best equipped in the west. It is gratifying also to state that experiments seem to have demonstrated that in ovens of proper construction certain at least of the Iowa coals can be coked, and arrangements are now being made to build the first battery of ovens at Des Moines. The value of Iowa coal for steaming purposes has been undoubted and certain boiler tests made at the capitol this year show it to be even better than commonly believed, slack coal evaporating 5.01 to 5.55 pounds of water per pound of coal at 212°, which results in a cost for fuel per horse power of 3.07 and 2.76 cents for twelve hours. This is interesting as showing what may be actually attained under working conditions. If any considerable portion of the coal can be prepared for metallurgical work within practical cost limits, it will open a new field for the Iowa mines and prove of great importance to the state.

That Iowa contains large quantities of material such as is elsewhere used for the manufacture of Natural and Portland cement, has been known for some time, and in view of the present large demand for cement it was thought well to make an investigation with a view to determining whether any of this material was so situated as to be available under present conditions. Mr. Bain was accordingly detailed to the work. The preliminary examinations have been completed and the results are so far quite favorable. It is hoped that a full report upon the subject may before long be furnished.

In the meantime the gypsum industry continues in a flourishing condition and makes annually a large contribution to the plaster output of the country. The small number of pro-

ducers in the local field makes it impracticable to publish statistics of this industry without unduly revealing details of a private business nature. With this exception, however, the statistics published by the Survey are very complete. Last year not a single producer of any importance failed to reply. The statistics will be again collected this year in connection with the United States Geological Survey.

The work of collecting soil samples as outlined in my last report has been steadily carried on and the material is now in the hands of the chemist for examination. Professor Weems has made numerous other analyses and examinations for the Survey as detailed in his report accompanying this.

Within the year volume IX of the Survey reports has been printed and distributed. The maps for volume X are now well under way and our first bulletin, "The Grasses of Iowa" by L. H. Pammell, J. B. Weems, and F. Lansom-Scribner, is now in the hands of the printer. The demand for the reports of the Survey has been so great that only volumes VIII and IX can now be supplied except by sale. A change made in revising the code, to which attention has only been called within the last few weeks, directs that 1,000 copies of the annual report shall be bound in the public documents. This will relieve the pressure for copies of the report considerably. The office work at Des Moines has been carried on as before except that during the first months of the year Dr. Beyer assisted in it. A simple laboratory equipment has been put in at Des Moines so that blow pipe and similiar tests can be made there. Many of the specimens sent to the Survey for examination require only such a test as can be made in a few minutes, now that the equipment is at hand.

One of the important results of the work of the Survey has been the bringing together of a strong corps of assistants. With the opportunity which the Survey work has afforded the various members of the corps have acquired familiarity with the methods of research, with the problems in hand and with the field itself. This added experience is reflected in the greater

accuracy of the work and the added rapidity with which it can be executed. The training of a force of even experienced geologists in the needs of a particular field is a work of time, and the results accomplished in this work are not among the least important that the Survey has to present.

I have the honor to remain, gentlemen,

Yours very sincerely,

SAMUEL CALVIN.

REPORT OF ASSISTANT STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY,
DECEMBER 26, 1899.

MY DEAR SIR—I have the honor to submit to you the following report upon my year's work.

Portions of February and March and May were spent under leave of absence, in work in other states. While this shortened somewhat the field season in Iowa it also lessened the season's expense and is believed to have been a distinct advantage to the local work in that it made possible wider comparisons and deeper study of local phenomena. My absence was made possible by the hearty co-operation of Dr. S. W. Beyer who, in the earlier portion of the year, relieved me of much of the usual office work. It was impossible to delegate all of this, however, and as before much time has been taken up with the details of illustrating, printing and binding the work in press during the year.

The correspondence has also been unusually heavy. The revival of business and the ease with which money can be obtained for investment, together with a better understanding of the facilities of the Survey, has brought more than the usual number of inquiries with regard to our mineral resources. It is impossible to answer all of these by means of printed matter, and a single letter often entails a day's search for the desired information. It is believed, however, that in no way is the Survey as directly fulfilling its duty in stimulating the development of the mineral resources of the state, and the letters of thanks for such service received from railways, mine owners, manufacturers, bankers, editors and others, indicate that the work is fully appreciated.

Aside from this general work my own efforts have been devoted mainly to the continued study of the lead and zinc fields of the state and to a search for material suitable for manufacture into Portland and other cements. It is a great pleasure to be able to report that the development work of the year at Dubuque tends to confirm the opinion arrived at last year, that there are important bodies of zinc blende to be mined in the region. The deeper work in the Alpine mine has continued to show good ore. The Avenue Top, Longworthy and Bush mines, all of which have been operated to some extent this year, show good ore bodies with every indication of a continuance of the jack to a considerable depth. The Pikes Peak mine, developed this year by pumping out one of the best known of the old lead ranges, has proven an important producer of jack. At present development work is being carried on on the Locky, Levens, and other crevices with every indication of success, and arrangements are being made to open up a considerable number of others. The Dubuque Ore Concentrating Company has built and equipped a large mill to handle the ores of the district, and it is believed that with better preparation of the ore, much better prices can be obtained. Further details are presented in the report upon Dubuque county, now in preparation for publication in this volume.

In the matter of cement material it is too soon to publish results. Personal visits have been made to, and suites of samples representing average quantities of each layer exposed have been collected from, some seventeen different localities. In addition smaller quantities, collected by myself or other members of the Survey, have been examined from a large number of other points. Some of these samples have been analyzed and the remainder are now in the hands of a chemist who has had large experience in the manufacture of cement. It may be stated that favorable material has already been found, but until the investigations are completed it is thought better to publish no results. The cost of a modern cement

mill is large and its success depends often as much on matters of fuel and industrial conditions as on the mere presence of suitable material. The industry is one requiring high technical skill and it is hoped that before publication an opportunity may serve for acquiring a wider knowledge of the actual manufacture of cement. The work will be pushed as rapidly as possible and a preliminary report will be submitted at the earliest practicable moment.

In the organization of a joint commission for the investigation of clays I had the pleasure of taking part. The work since the organization has, however, been wholly in Dr. Beyer's charge and I have devoted but little attention to it.

In mapping, my personal work has been confined to the completion of certain areas in Dubuque county, left over from last year. I have, however, held field conferences with Professor Norton in Bremer county, Professor Udden in Louisa, Professor Miller in Marion, Professor Macbride in Osceola and Dickinson and Mr. Wilder in Lyon and Sioux. In company with Mr. Wilder I made a bicycle journey from Carroll county northwest as far as Sioux Falls, studying the drift of the intervening region. Mr. Wilder then took up the problem and his report, appearing in this volume, shows how successfully he has attacked it. I have been over most of the region in his company or alone, and would wish heartily to concur in his findings. Very respectfully,

H. F. BAIN,
Assistant State Geologist.

TO PROF. SAMUEL CALVIN,
State Geologist.

REPORT OF W. H. NORTON.

CORNELL COLLEGE,
MT. VERNON, Iowa, December 23, 1899.

Dr. Samuel Calvin,
Director Iowa Geological Survey:

SIR—I herewith submit a report of my work for the current year as an assistant upon the Iowa Geological Survey.

During last summer the field work in Cedar county was completed, and that in Bremer also nearly finished. The manuscript of the Cedar county report is nearly written and will be presented in due time for publication in the forthcoming annual report of the Survey. Both of these areas were found unexpectedly rich in geologic interest, and a detailed statement of their resources can hardly fail to be of economic value.

The office maintained by the Survey in the department of artesian wells has steadily increased in usefulness. So far as known no deep well has been drilled recently without consulting with the Survey except in towns where the artesian conditions were already well known from previous borings. Copies of the writer's report on the Artesian Wells of Iowa have been widely distributed throughout the state, and in a number of towns intelligent citizens have made themselves thoroughly familiar with the artesian possibilities of their localities. In nearly every instance where a deep well was under advisement, requests have been made to this office for detailed specifications as to the depth, and the quality and the quantity of artesian water. Several towns have requested a personal examination of the local conditions. Advice has

also been asked as to the prosecution of the work of drilling, and in this way several thousand dollars have been saved to the consulting municipalities. Of still greater value, perhaps, is the professional advice freely given in encouragement of enterprises under consideration.

It is a pleasure to mention the most cordial co-operation which has been furnished in securing records and sample drillings of the recent deep wells of the state. The data thus obtained are of great value, whether they rectify or corroborate the conclusions already reached as to the deeper strata of Iowa, and the artesian conditions dependent upon them. Each well sunk is a test of the accuracy of the geologic maps and sections already published in our reports, and so far the results of the application of these tests has been most gratifying. So nearly, for example, has the depth to the first chief aquifer, or water-bearing stratum, been calculated, that the discrepancy between this and the actual depth at which it was reached by the drill is in no instance, so far as known, greater than the variation in the thickness of the aquifer.

Such is the value of the facts accumulated since the publication of the reports on the artesian wells of the state, that it would seem well to place them on permanent record as a supplemental report in the early future.

Since my last report to you professional advice has been given to owners or projectors of deep wells in the following towns:

Within the last thirty days estimates have been made out for wells at Muscatine and Letts.

At Sumner a deep well is now being put down by the town. Throughout the work this office has been in close touch with it, receiving the fullest information from time to time, and samples of the drillings. Our last communication was early in December, when we advised the town to carry the well still deeper.

The town of Waverly completed in August a fine artesian, discharging between 300 and 400 gallons a minute of pure and

delicious water. The committee in charge consulted with us when the contract was let last February, and at intervals during the prosecution of the work. When the well had reached a depth of 1,718 feet, I was called to Waverly by the council to consult as to the advisability of carrying the well to greater depth. Although the almost unanimous opinion had favored sinking the well several hundred feet deeper, a presentation of all the facts bearing upon the case brought about as great an unanimity to the contrary, and the work was stopped at once. Several complete sets of samples of the strata penetrated were saved and one of these has been given to the Survey. In our published map showing the altitude of the St. Peter, the height of it at Waverly was placed at 200 A. T. This sandstone was reached by the driller at 238 A. T.

Last April the city council at Marshalltown applied for information as to the possibility of obtaining artesian water for municipal supply. It was stated that 2,000,000 gallons daily would be necessary. In reply the distance was stated to the chief aquifers at that station. These were found to lie within practicable limits, but no encouragement could be given that the amount of water considered needful could be obtained.

One, also, of the large manufacturing establishments of the city consulted with this office with regard to the same general questions, and upon study of the chemical constituents of the deeper waters of this region as shown in published analyses in our report, abandoned its project of sinking a deep well, since the waters would probably be unsuited to their specific purpose.

In September last inquiries were made by the city council at Bloomfield as to methods of drilling, reliability of drillers, and artesian possibilities at that locality. In the same month the question was presented of methods to secure in the well now drilling at West Liberty a less heavily mineralized water than that obtained in the first well sunk in that town.

In the course of the survey of Cedar county during the summer, a set of drillings from the Tipton artesian was obtained more complete than that used in our previous reports. We shall thus obtain a better section of one of the deepest borings in the state.

In February the office was asked for an opinion as to the possibility of obtaining artesian waters at Chariton, and in reply a full statement was sent, showing depth to the aquifers, geologic conditions, etc.

In the same month an interesting artesian was completed at Osage. Some two years earlier our advice had been asked on the subject and a strongly encouraging letter stating the geologic situation was published in the local papers. In this letter the probable depth to the St. Peter was estimated at from 700 to 750 feet from the surface. In the well lately finished this formation was reached at about 720 feet. The main aquifers of the Iowa field were not here penetrated, the drill stopping at 780 feet at the base of the St. Peter, with a supply of water which seems to have appeared sufficient to those in charge of the work. If it should prove inadequate to the needs of the growing town, the well can easily be sunk to the more generous water-bearers a few hundred feet below.

The deep well at Crapo Park, Burlington, was not drilled under the supervision of this office and we have been unable to secure samples of the strata penetrated. These, however, were carefully studied by Mr. F. M. Fultz, who published a most complete and valuable paper on the geological section in the 1899 report of the Iowa Academy of Sciences. When the well had reached a depth of 1,520 feet we were consulted by the park commissioners as to the probability of securing a higher head of water by going deeper. It had been thought that perhaps by going to the depth of 2,300 feet artesian water would be encountered under the same head as at Boone and at Des Moines. Such an expectation was without foundation and could not be encouraged, and though the well was sunk to 2,430 feet no additional head was obtained.

At the Iowa Hospital for the Insane at Mount Pleasant a well was finished last year of which a record has been supplied, and it is promised that a set of sample drillings will be furnished for examination. At the same time several citizens of Mount Pleasant consulted with us on the question of artesian municipal supply, quality of water, position of well, etc.

Two artesians have recently been drilled at Dubuque, two at McGregor, one at Anamosa, and one at Clinton. Of these more or less complete records have been preserved, and will, doubtless, prove of value, although the stratigraphy of each of these localities is fairly well known from previous borings.

Wells are now being sunk at Iowa Falls and at Hampton. At both towns we arranged with responsible persons for complete records and samples of the drillings, and it is hoped that these important borings may make a marked contribution to our knowledge of the deep strata of Iowa. In these, as in all cases similar, those in charge of the work were promptly communicated with and informed that the services of the Survey were placed at their free use.

I have the honor to remain,

Your obedient servant,

WILLIAM HARMON NORTON.

REPORT OF S. W. BEYER.

IOWA GEOLOGICAL SURVEY,
DES MOINES, Iowa, December 30, 1899.

MY DEAR SIR—I have the honor to submit the following report of work done by me during the year ending December 30, 1899. During the first quarter of the year my time was occupied thoroughly in the routine work of the office and sharing with Mr. Bain the work of getting volume IX through the press. The work of compiling the mineral statistics of the state for the year was assigned to me. In the capacity of statistician of the Survey several trips were made to the chief mineral-producing centers of the state. The report on the mineral output for 1898 appears in volume IX.

In June, at a conference composed of representatives from the Iowa Brick-makers' Association, Iowa Engineering Society, Iowa Geological Survey, the Iowa State College and the State University, held at Ames, it was decided to undertake an investigation of the Iowa clays, the work to be done jointly by the institutions concerned, the Survey to undertake the field investigations in the collection of both the raw materials and the manufactured products for further investigations in the laboratories of the State College and the University. It was deemed best that for the current year the inquiry be confined to paving brick. It was my good fortune to be appointed to represent the Survey.

The works at Ottumwa, Oskaloosa, Davenport, Burlington, Fort Dodge, Sioux City, Boone, and Des Moines were visited. Experiments were conducted at Boone, Burlington and Des Moines. It was deemed best to study methods actually in

use and to test products not especially made to be tested but as actually put upon the market. A complete history of the clay from the pit to the finished product was desired and could only be obtained by personal observations at the factories. It was believed to be important that the character of the clays and shales should be carefully noted, that the shrinkage be determined volumetrically and by weight and that the conditions of drying and the actual burning temperatures for the various portions of the kiln be ascertained.

With the above facts in mind the pit sections were examined carefully and the different strata noted. The green brick as they came from the machine were weighed, numbered and measured. The brick were again weighed and measured as they came from the drying kiln, and once more when taken from the burning kiln. Seventy-five brick were experimented on. These marked brick were separated into three groups of twenty-five each and placed at three points in the kiln. The first series was placed near the center and at the bottom of the kiln, the second group at the upper central portion, and the third series at the top near the bags and but little or not at all protected from the direct heat of the furnace. A series of Seger's temperature cones were placed with each group. Liberal samples of the separate beds of clays and shales were collected for a study of the physical and chemical properties, and the marked brick, along with an additional number of brick selected from the same place in the kiln, were shipped to Ames to be subjected to various tests known to engineers and believed to determine the qualities of brick. Duplicate series were shipped to Iowa City for similar tests. The work is not far enough along to warrant generalization or the statement of definite results. This much may be said, however, that all of the factories visited utilize a hetrogeneous series of clays and shales, varying greatly in composition and structure, that the average shrinkage varies from 20 to 35 per cent volumetrically and from 20 to 25 per cent by weight and that the

burning temperature varies from 1900° F to 2300° F. Complete vitrification is not far from 2500° F.

No work has yet been done on the chemistry and physics of the clays, and testing of the manufactured product is only begun.

One week of the field season was spent completing the work in Hardin county and the report on the county is now well under way.

Very respectfully yours,

S. W. BEYER.

TO PROF. SAMUEL CALVIN,

State Geologist.

REPORT OF J. B. WEEMS.

AMES, Iowa, December 21, 1899.

SIR—I have the honor of presenting the following report relating to the chemical work of the Survey:

During the year the analyses which have been made are as follows:

NO. OF SAMPLES.		NO. OF DETERMINATIONS.
12	samples of rock for determination of phosphoric acid	12
9	samples of limestone	81
5	samples of zinc ores	5
1	sample of copper ore	1
2	samples of slag	22
1	sample of slate	9
	Total determinations	130

All of the above determinations are made in duplicate. In addition to the above there has been other work on the co-operative work between the Survey and the Experiment Station in its botanical and chemical sections in an investigation of the grasses of the state. This investigation is now almost ready for the press, and will probably be published in the near future.

The investigation on the soils of the state by the chemical section and the Survey is still in progress and is advanced as much as it is possible to expect considering the amount of routine work of the section.

It may be well to call attention to the practical work of the Survey as a valuable adjunct to the regular geological work and under this consideration the soil work would naturally be placed. The state of Iowa is naturally an agricultural state and investigations which will aid the farmer in coming to

understand the soils, which present some of the most complicated problems, will be of the utmost value to the state at large. There is always an opportunity for valuable investigations of this nature, and it is hoped that in the coming years the Survey will be the means of rendering much valuable aid to the farmers of the state.

Very respectfully submitted,

J. B. WEEMS.

TO PROF. SAMUEL CALVIN,
State Geologist.

MINERAL PRODUCTION OF IOWA.

IN 1899

BY

S. W. BEYER.

VALUE OF MINERAL PRODUCTION.

Coal	$ 6,137,576
Clay (estimated)	2,500,000
Stone	809,924
Gypsum (estimated)	600,000
Lead and zinc	50,542
Iron ore	3,465
Total value	$10,101,507

MINERAL PRODUCTION OF IOWA IN 1899.

BY S. W. BEYER.

The year was characterized by great activity in all of the industries; the greatest, perhaps, the country has ever known. This was especially true of the so-called extractive industries of which mining is one. The output for the year shows great gains in every department, not only in quantity but more especially in price. The output of coal increased nearly 10 per cent, while the average price per ton shows a net gain of 11 cents per ton. The production of stone increased almost a quarter of a million dollars, or more than 43 per cent. The statistics for clay are not in hand, but a conservative estimate would place the total output at least 25 per cent greater than for the preceding year. The lead and zinc industry shows a healthy growth and, for the first time, Iowa must now be listed as one of the states producing iron ore in commercial quantity. The gypsum industry enjoyed a most flourishing year and the value of the output exceeded a half million dollars.

As in 1898, the work of gathering statistics has been carried on jointly by the State and Federal Surveys, save in the case of clays. The work of compiling the clay production has been undertaken by the Federal Census Bureau and the figures are not yet available.

TOTAL PRODUCTION.

The value of the mineral production in 1899 was $10,101,507, distributed as follows:

	Value.	No. of producers.
Coal	$6,137,576	203
Clay (estimated)	2,500,000	360
Stone	809,924	175
Gypsum (estimated)	600,000	6
Lead and zinc	50,542	9
Iron ore	3,465	1
Total	$10,101,507	754

The United States Geological Survey placed the value of the mineral output of the state for 1898 as follows:

Coal	$5,260,716
Clay	2,150,822
Stone	531,648
Lead and zinc*	43,784
Total	$7,986,970

The production is shown by counties for all, save clay, in Table I.

*Iowa Geological Survey.

TABLE I—TOTAL MINERAL PRODUCTION BY COUNTIES, SAVE FOR CLAY.

COUNTIES.	Total coal.	Total stone.	Miscellaneous.	Total.
Adams	$ 34,920			$ 34,920
Allamakee		$ 53	$ 3,465	3,518
Appanoose	885,358			885,358
Benton		3,857		3,857
Black Hawk		5,289		5,289
Boone	424,018			424,018
Cedar		114,455		114,455
Cerro Gordo		11,784		11,784
Clayton		7,867		7,867
Clinton		1,136		1,136
Dallas	16,992			16,992
Decatur		1,188		1,188
Delaware		1,446		1,446
Des Moines		162,188		162 188
Dubuque		36,386	50,542	87,928
Fayette		12,135		12,135
Floyd		4,025		4,025
Greene	21,430			21,430
Hardin		11,831		11,831
Howard		1,256		1,256
Humboldt		4,900		4,900
Jackson		67,659		67,659
Jasper	273,354			273,354
Johnson		26,348		26,348
Jones		76,596		76,596
Keokuk	396,671	3,194		399,865
Lee		27,184		27,184
Linn		50,800		50,800
Louisa		2,320		2,320
Lucas	5,925			5,925
Madison	1,428,201	2,991		1,428,201
Mahaska		9,196		9,196
Marion	248,046	7,497		255,543
Marshall		57,751		57,751
Mitchell		3,472		3,472
Monroe	714,062			714,062
Montgomery		2,178		2,178
Page	9,000			9,000
Polk	947,650			947,650
Scott	12,193	31,466		43 659
Story	16,164			16,164
Tama		440		440
Taylor	22,110			22,110
Van Buren	11.077	2,893		13,970
Wapello	361,027	15,020		376,047
Warren	21,629			21,627
Washington		4,718		4,718
Wayne	84,610			84,610
Webster	193,139		600,000	793,139
Single producers		23,388		23,388
Total clay output estimated				2,500,000
Total	$6,137,576	$809,924	$654,007	$10,101,507

COAL.

The output of coal for 1899 shows a marked increase over that of the preceding year, both in tonnage and price. In fact the output was greater than for any year in the history of the industry in the state. The average price per ton was greater than for any year since 1894. The actual selling price was, in many instances, far below the real market price, on account of contracts made early in the season. Of the total output less than 10 per cent was sold locally or consumed at the mine. The average number of days worked was notably greater than for the preceding year. Table II gives the total tonnage, average price per ton, total value, number of mines producing, average number of days worked and number of men employed, arranged by counties.

TABLE II—COAL OUTPUT BY COUNTIES.

COUNTIES.	Minns producing.	TONS.	Average price per ton.	VALUE.	Average No. days worked.	Men employed.
Adams	6	19,821	$ 1 60	$ 34,920	170	50
Appanoose	42	633,899	1.40	885,358	215	2,091
Boone	13	262,632	1.61	424,018	205	896
Dallas	3	10,813	1.57	16,992	255	37
Greene	5	13,289	1.61	21,430	225	61
Jasper	8	214,677	1.27	273,354	197	320
Keokuk	11	336,065	1.18	396,671	220	536
Lucas	1	3,700	1.60	5.925	150	25
Mahaska	16	1,277,248	1.12	1,428,201	270	2,223
Marion	15	232,351	1.06	248,046	235	487
Monroe	9	684.004	1.04	714,062	215	1,201
Page	3	4,000	2.25	9,000	150	26
Polk	18	691,989	1.37	947,650	230	1,087
Scott	2	7,348	1.75	12,193	264	34
Story	2	6,788	2.38	16,164	200	29
Taylor	2	12,165	1.82	22,110	220	36
Van Buren	2	7,385	1.50	11,077	240	15
Wapello	13	316,460	1.14	361,027	270	568
Warren	4	14,655	1.48	21,629	220	32
Wayne	3	60,418	1.40	84,610	158	224
Webster	15	118,770	1.64	193,139	220	310
Total	203	4.928,477	$1.25	$6,137,576	229	10,268

In gathering the statistics for coal it is not always possible to secure separate reports for the various sizes of coal put upon the market. In the above table no attempt has been made to make such a separation. Mine run, nut and slack are included in the total, hence the average price for lump coal would be materially higher than the figures given in the table.

The average number of days worked was greater than for any year on record, save 1892, while the number of men employed was about the same as for 1898. The average number of days worked and the number of men employed during the past eight years, according to the best information available, was as follows:

YEARS	Average number of days worked.	Number of men employed.
1892	236	8,170
1893	204	8,863
1894	170	9,995
1895	189	10,066
1896	178	9,672
1897	201	10,703
1898	218	10,256
1899	229	10,268

In 1898 according to the authority of U. S. Geological Survey, Iowa ranked eighth in tonnage and fifth according to the value of output.

She still maintains her rank in first place of the coal producing states west of the Mississippi. The ten leading coal producers ranked as follows for 1899:

RANK.	STATE.	TONS.	VALUE.	Av. price per ton.
1	Pennsylvania	65,165,133	$43,352,588	$ .67
2	Illinois	18,599,299	14,567,598	.78
3	West Virginia	16,700 999	10,131,264	.61
4	Ohio	14,516,867	12,027,336	.83
5	Alabama	6,535,283	4,932,776	.75
6	Indiana	4,920,743	3,994,918	.81
7	Maryland	4,674,884	3,532,257	.75
8	Iowa	4,618,842	5,260,716	1.14
9	Colorado	4,076,347	4,686,081	1.15
10	Kentucky	3,887,908	3,084,551	.79

In some respects the statistics given in the report of the state mine inspectors gives a better idea of the remarkable increase in the amount of coal produced during the winter of

Table III compares the output for 1899 with the output for the five preceding years:

TABLE III.

YEARS.	Short tons.	Price.	Value.	AUTHORITY.
1894	3,967,253	$1.26	$4,999,939	U. S. Geol. Survey
1895	4,156,074	1.20	4,982,102	U. S. Geol. Survey
1896	3,954,028	1.17	4,628,022	U. S. Geol. Survey
1897	4,611,865	1.13	5,219,503	U. S. Geol. Survey
1898	4,618,842	1.14	5,260,716	U. S. Geol. Survey
1899	4,928,477	1.25	6,137,576	Iowa Geol. Survey

1898 and 1899. According to the ninth biennial report of the state mine inspectors, the output of coal for the year ending June 30, 1899, was as follows by counties:

TABLE IV—COAL OUTPUT FOR YEAR ENDING JUNE 30, 1899.

COUNTIES.	Coal produced.	Number of men.	Av. selling price lump coal at mine.
Adair	4,000	24	$2.00
Adams	22,800	143	2.00
Appanoose	444 282	1,854	1.25
Boone	371,410	995	1.51
Dallas	13,600	61	1.65
Davis	3,300	23	1.25
Greene	22,500	106	1.43
Guthrie	16,400	100	2.00
Jasper	188,800	358	1.25
Jefferson	4,500	29	1.75
Keokuk	281,395	609	1.25
Lucas	12 800	74	1.50
Mahaska	1,374,798	2,343	1.25
Marion	141,780	284	1.24
Monroe	662,500	1,137	1.18
Page	6,085	52	2.00
Polk	790,410	1,326	1.37
Scott	11,800	57	1.60
Story	9,600	45	1.65
Taylor	14,100	49	1.75
Van Buren	12,500	38	1.35
Wapello	291,300	500	1.18
Warren	15,000	72	1.50
Wayne	48,300	204	1.30
Webster	185,350	510	1.43
Total	4,949,307	11,029	......

CLAY.

As has been mentioned the collection of the statistics on clay products is in the hands of the Federal Census Bureau and is not available for this report. The demand for all sorts of clay goods has been strong, and in building brick the demand exceeded the supply. In several of the leading clay-working centers the orders were several months ahead of the manufacturers throughout the season. Prices were sharply advanced and goods were generally sold at a good price, Here as in the case of coal a few suffered by making contracts early in the season. A moderate estimate would place the output 25 per cent greater than for 1898, or $2,500,000 worth of clay goods were manufactured and marketed during the year.

In 1898 Iowa ranked eighth in the value of clay products, producing 3 per cent of the total output of the country. The following table shows the rank of the ten leading states according to the United States Geological Survey.

TABLE V.

RANK.	STATE.	Number of operating firms reporting.	VALUE.	Per cent of total product.
1	Ohio	866	$12,412,437	17.34
2	Pennsylvania	473	9,642,098	13.47
3	New Jersey	133	8,599,367	12.01
4	Illinois	616	6,705,393	9.37
5	New York	265	6,448,989	9.01
6	Indiana	592	3,211,512	4.49
7	Missouri	228	3,055,206	4.27
8	Iowa	357	2,150,822	3.00
9	Massachusetts	104	1,776,770	2.48
10	Maryland	69	1,253,425	1.75

During the same year she ranked fourth in the production of vitrified paving brick, thus bettering her grade by one both in total clay output and in paving brick. The leading states in the production of paving brick for 1898 are listed below:

TABLE VI—PAVING BRICK IN 1898.

RANK.	STATE.	Thousands.	Value.	Price per thousand.
1	Ohio	115,104	$796,935	$ 6.92
2	Illinois	71,999	639,153	8.88
3	Pennsylvania	59,014	513,391	8.70
4	Iowa	35,357	289,963	8.20
5	Indiana	28,216	264,796	9.38
6	Missouri	28,036	264,092	9.42
7	Kansas	27,632	200,022	7.24
8	New York	27,532	302,680	10.99

STONE.

The stone trade continued strong through 1899. The government improvements being made along the Mississippi river created a great demand for stone suitable for riprap and rubble work. This improvement is responsible for the large increase in the output of Des Moines county over the preceding year. The production of lime shows a slight decrease and more than a corresponding decrease in demand, owing to the extension of the use of rock and Portland cements to lines of work formerly occupied exclusively by lime. The stone quarried includes limestone, dolomite and a small quantity of sandstone. Most of the quarries are small, and but few are equipped with improved machinery. The returns show an output of $809,924 for the year, or a net gain of $246,338. The production was distributed as follows:

LIMESTONE—USED FOR.

Building purposes	$330,268
Paving or road making	162,068
Riprap	126,583
Lime	102,686
Other purposes	71,080
Sandstone	17,239
Total	$809,924

The production by counties is given in Table VII:

TABLE VII—VALUE OF STONE PRODUCED IN IOWA FOR 1899.—LIMESTONE.

COUNTIES.	Building purposes.	Paving or road-making.	Riprap.	Lime.	Sold to lime burners.	Other purposes.	Total value.
Allamakee	$ 3			$ 50			$ 53
Benton	840		$ 17	3,000			3,857
Black Hawk	4,563	$ 20	15				4,598
Cedar	8,754	94,325	876	10,500			114,455
Cerro Gordo	4,615	3,559	250	3,360			11,784
Clayton	5,917		75	1,875			7,867
Clinton	986	150					1,136
Decatur	911	187	90				1,188
Delaware	1,389	50	7				1,446
Des Moines	35,165	21,042	72,981			$33,000	162,188
Dubuque	28,976	1,660	4,500	3,250			36,386
Fayette	11,135			1,000			12,135
Floyd	3,725	200	100				4,025
Hardin	10,981	100	500	250			11,831
Howard	1,191	40	25				1,256
Humboldt	4,900						4,900
Jackson	375	625	100	66,559			67,659
Johnson	2,415	1,405	22,528				26,348
Jones	67,569	3,618	5,159	200		50	76,596
Keokuk	2,718	300	100			76	3,194
Lee	19,134	4,940	2,976		$ 5	129	27,184
Louisa	1,950	350	20				2,320
Linn	16,710	4,540	2,400	10,150		17,000	50,800
Madison	2,958		33				2,991
Mahaska	7,629	507				1,060	9,196
Marion	6,120	820	448			109	7,497
Marshall	21,475	16,100	4,176			16,000	57,751
Mitchell	922		63	987	1,500		3,472
Montgomery	953	200	25			1,000	2,178
Scott	17,487	4,999	6,550			2,430	31,466
Tama	400	17	23				440
Van Buren	2,363	50	480				2,893
Wapello	13,240	530	1,250				15,020
Washington	3,497	729	311			181	4,718
Single producers	20,302	1,005	505			45	21,857
Total	$330,268	$162,068	$126,583	$101,181	$1,505	$71,080	$792,685

SANDSTONE.

COUNTIES.	Sold in rough.	Building purposes.	Curbing and flagstone.	Total values.
Black Hawk	....	$ 691	....	$ 691
Single producers	$2,019	13,179	$1,350	16,548
Total	$2,019	$13,870	$1,350	$17,239

In 1898 the state ranked nineteenth among the stone producers and eighth in the value of its limestone. The ten states leading in the production of limestone for 1898, according to the United States Geological Survey, were as follows:

TABLE VIII.

RANK.	STATE.	VALUE.
1	Pennsylvania	$2,746,256
2	Indiana	1,686,572
3	Ohio	1,673,160
4	New York	1,533,936
5	Illinois	1,421,072
6	Missouri	735,275
7	Wisconsin	698,454
8	Iowa *	557,024
9	Maryland	433,653
10	Minnesota	345,685

The value of the stone produced in Iowa during 1899 and the seven years preceding, was as follows:

TABLE IX.

YEAR.	Sannstone.	Limestone.	Total.
1892	$25,000	$705,000	$730,000
1893	18,347	547,000	565,347
1894	11,639	616,630	628,269
1895	5,575	449,501	455,076
1896	12,351	410,037	422,388
1897	14,771	480,572	495,343
1898 (Iowa Geological Survey)	6,562	557,024	563,586
1899	17,239	792,685	809,924

* Iowa Geological Survey.

GYPSUM.

The output of gypsum for 1899 was the greatest since the establishment of the industry. The building revival, coupled with new uses to which the product is put, greatly stimulated its production. Two new mills were put in operation during the year and those already established were run to their full capacity and overtime for a portion of the year. R. W. Crawford & Co. began operations early in the year while the Mineral City began the sinking of a shaft in November but did not produce until 1900. The first is equipped with two kettles and the latter three, making a total of nineteen kettles for the district. The capacity is about 600 tons of plaster for a nine-hour shift.

The output for 1899 exceeded 120,000 tons of plaster, valued at $600,000, at the mills.

LEAD AND ZINC.

The activity which marked the rejuvenated lead and zinc mines in and about Dubuque during the latter part of 1898, continued unabated throughout 1899. Facilities for handling the ore have improved greatly. Formerly the ore was hand-picked and sent out of the state for concentration. Early in 1899 a modern mill, fully equipped, was established by the Dubuque Ore Concentrating company. The installation of this much needed plant has greatly stimulated local production. The Allamakee and Clayton county mines were not producing during 1899 and all of the ore came from the Dubuque region.

The lead output shows a considerable falling of in quantity but a higher price. About 1,000,000 pounds were sold, valued at $30,000.

The zinc production shows a marked increase over 1898. The product marketed consists chiefly of dry bone, which averaged $10 per ton. Some blende was sold at an average price of $25 per ton. Summarizing, the output was as follows:

Lead	1,000,000 pounds	$30,000
Zinc	2,174 tons	20,542
Total		$50,542

IRON.

For the first time in the history of the mineral production in Iowa, the state has entered the list as an iron producer. The product is a brown hematite and the entire output was sold to the Illinois Steel company. The occurrence and composition of the ore is fully treated in the administrative report of the director in this volume.

In 1899, 1,260 tons of ore were produced and sold for $3,465.

THE SUCCESSION OF FOSSIL FAUNAS IN THE KINDERHOOK BEDS AT BURLINGTON, IOWA.

BY

STUART WELLER

THE SUCCESSION OF FOSSIL FAUNAS IN THE KINDERHOOK BEDS AT BURLINGTON, IOWA.

BY STUART WELLER.

The stratigraphic succession of the Mississippian beds at Burlington, Iowa, was first indicated by David Dale Owen* in 1852. At that time the Kinderhook stage or its equivalent had not been defined, but the lower portion of his general section, that portion which is now included in the Kinderhook, was described as follows:

5. Band of cellular, buff, magnesian limestone.
4. Oolitic limestone containing *Gyroceras Burlingtonensis*.
3. Dark gray argillaceous limestones (locally hydraulic?)
2. Buff, fine-grained siliceous rock, containing casts of *Chonetes*, *Posidonomya*, *Allorisma*, *Spirifer*, *Phillipsia*.
1. Ash colored, earthy marlites.

At that time Owen included all the strata down to the base of his No. 3, in the "Encrinital Group of Burlington." It is not possible to determine from his section the exact thickness attributed to each individual stratum recognized, but their aggregate is indicated in his table as about 100 feet, of which the lowest member, No. 1 is about 60 feet.

In 1858 Hall's report on the Geology of Iowa was published, and the following section is given of the rocks at Burlington of the Kinderhook stage, at that time referred to the "Chemung Group."†

*Rep. on Geol. Wis., Iowa and Minn., p. 93. (1852)
†Rep. Geol. Surv. Iowa, Vol. 1, pt. 1, p. 90. (1858.)

			Feet.
Chemung Group.	5.	Oolitic bed (often absent) its greatest thickness...	¼
	4.	Argillaceous sandstone with fossils as below, of Chemung species................................	6
	3.	Limestone, irregularly bedded, concretionary and rarely brecciated, with shaly interlaminations; compact, brittle, ash-colored, apparently siliceous. Higher beds more regular and arenaceous; near the base, a thin band of limestone charged with *Chonetes*......	10
	2.	Fine-grained, siliceous and argillaceous sandstone, with bands of shale, highly fossiliferous; lower half much softer and more argillaceous than the upper part (often shaly)..........................	25
	1.	Soft green shale like that of Portage group, to level of river....................................	32

In 1860 C. A. White published a paper entitled, "Observations upon the Geology and Paleontology of Burlington, Iowa, and its Vicinity,"* in which the Kinderhook section at Burlington was described, and later, in 1870, while he was State Geologist, the section was again described in his official report.† In White's section seven beds were recognized as follows:

		Feet.
7.	Impure limestone, sometimes magnesian, passing gradually into the Lower Burlington limestone..	3-4
6.	Light gray oolitic limestone with uniform lithological characters..............................	2-4
5.	Fine-grained yellowish sandstone much like parts of No. 1, often crowded with casts of fossil shells. Maximum thickness.............................	7
4.	Dark gray compact limestone, sometimes slightly arenaceous. It breaks up into small fragments upon exposure, and is very fragmentary even when not exposed to the atmosphere. Maximum thickness.......	12
3.	Band of oolite limestone about....................	½
2.	Band of compact limestone everywhere crowded with *Chonetes*....................................	½
1.	Fine-grained sandy shales, varying from bluish clay shale to fine-grained yellow sandstone. The upper portion of the bed quite fossiliferous. Greatest thickness actually exposed above river level 82 feet, its total thickness as estimated from well borings....................................	140-200

*Jour. Bost. Soc. Nat. Hist., Vol. 7, pp. 209-235. (1860.)
†Rep. Geol. Surv. Iowa, Vol. 1, pp. 192-193. (Des Moines, 1870.)

In his report on Des Moines county, Keyes*, in 1895, gives the following section of the Kinderhook beds at Prospect Hill, a bluff on the river bank just south of the city of Burlington:

		FEET.
6.	Limestone, buff, soft, sandy locally	5
5.	Limestone, white oolitic	3
4.	Sandstone, yellowish, soft, fine-grained, highly charged with casts of fossils	6
3.	Limestone, argillaceous, fine-grained, with often an oolitic band or thin bed of impure limerock at base	18
2.	Sandstone, yellowish, soft, friable, clayey	25
1.	Shale, blue, argillaceous, shown by borings to extend 100 feet or more below river level (exposed)	60

In March, 1899, the writer spent some time in the field, studying the Kinderhook section at Burlington, in order to differentiate the fossil faunas of that age there represented, and the following section which seems best adapted to bring out the faunal succession, has been adopted as the result of observations made at that time. It differs from Hall's and from Keyes' sections only in dividing their No. 3, recognizing as a distinct bed their band of impure or oolitic limestone. It differs from White's section only in joining his Nos. 2 and 3, and in dividing his No. 1, the upper sandy, fossiliferous portion being recognized as a distinct bed:

		FEET.
7.	Soft, buff, gritty limestone	3-5
6.	White oolit'c limestone	2-4
5.	Fine-grained, yellow sandstone	6-7
4.	Fine-grained, compact, fragmental gray limestone.	12-18
3.	Thin band of hard, impure, limestone filled with *Chonetes*; sometimes associated with a thin oolite band	$\frac{1}{2}$-$\frac{3}{4}$
2.	Soft, friable, argillaceous sandstone, sometimes harder and bluish in color, filled with fossils in the upper portion, the most abundant of which is *Chonopectus fischeri*	25
1.	Soft blue argillaceous shale (exposed)	60

The correlation of the Kinderhook beds at Burlington as recognized by these several observers is not a difficult matter, the preceding sections being but different interpretations or different arrangements of the same series of strata. In the following table these five sections are arranged side by side

*Geol. Surv. Iowa, Vol. 3, p. 433. (Des Moines, 1895.)

in such a manner as to correlate the divisions recognized in each, the divisions of the several authors being indicated by numbers only:

<table>
<tr><th>OWEN.
1852.</th><th>HALL.
1858.</th><th>WHITE.
1870.</th><th>KEYES.
1895.</th><th>WELLER.
1899.</th></tr>
<tr><td>5</td><td></td><td>7</td><td>6</td><td>7</td></tr>
<tr><td>4</td><td>5</td><td>6</td><td>5</td><td>6</td></tr>
<tr><td rowspan="4">3</td><td>4</td><td>5</td><td>4</td><td>5</td></tr>
<tr><td rowspan="3">3</td><td>4</td><td rowspan="3">3</td><td rowspan="2">4</td></tr>
<tr><td>3</td></tr>
<tr><td>2</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td rowspan="2">1</td><td>2</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>

RIVER LEVEL.

The fossils of the Kinderhook beds at Burlington, at one time attracted much attention from paleontologists and local collectors, but of late years they have usually been neglected. The first species described from any of the beds was *Gyroceras burlingtonensis*, described by Owen* in 1852, from the oolite bed No. 6 (Weller). A little later, in 1858, in his Paleontology of Iowa, Hall† described and illustrated a number of species of brachiopods and a few pelecypods from the "yellow sandstone" at Burlington.

The most important collection of Kinderhook fossils from Burlington that has been brought together was made by Dr. C. A. White when he was a resident of that city. The "White collection," which is now the property of the University of Michigan, formed the basis for several important papers devoted to the description of Burlington fossils by C. A. White[1], by C. A. White and R. P. Whitfield[2], and by A. Winchell.[3] In these papers many species were described but without illustrations, so that their identification by other observers and from other localities has always been exceedingly difficult or impossible.

During the preparation of the descriptions of New York Devonian pelecypods for the Paleontology of New York, Hall‡ described and illustrated several of the Burlington "yellow sandstone" species that were related to New York Devonian species, the figures in most cases being drawn from the type specimens. More recently Keyes§ has published upon some of the gasteropods from the Kinderhook beds at Burlington, but his identifications of the species were apparently not based on comparisons with the type specimens, and are evidently erroneous in some cases.

*Geol. Surv. Wis., Iowa and Minn., p. 581, tab. 5, fig. 10.

†Rep. Geol. Surv. Iowa, Vol. 1, pt. 2.

1 Proc. Bost. Soc. Nat. Hist., Vol. 9, pp. 8-33. (1862)

2 Proc. Bost. Soc. Nat. Hist., Vol. 8, pp. 289-306. (1862.)

3 Proc. Acad. Nat. Sci. Phil., 1863, pp. 2-25. (1863) Proc. Acad. Nat. Sci. Phil., 1865, pp. 109-133. (1865.)

‡Pal. N. Y., Vol. 5, pt. 1. (1884-1885.)

§Proc. Acad. Nat. Sci. Phil., 1889, p. 234 (1889), and Am. Geol., Vol. 5, p. 193. (1890.)

In all the work which has been done in the past on the Kinderhook fossils at Burlington, little or no effort has been made to assign the species to their definite stratigraphic positions in the section. It has usually been deemed sufficient to refer a species to the "yellow sandstone, Burlington, Iowa." ignoring the fact that there are two yellow sandstones in the Kinderhook at that place, whose faunas are almost entirely distinct, there being only a small number of species common to the two beds. The fauna of the oolite bed can be more easily recognized from the literature, but even the fossils from this well marked horizon have often been recorded simply as coming from the "Kinderhook beds, Burlington, Iowa."

The present paper is an attempt to distribute the Kinderhook species from Burlington into their several faunas. It is based primarily upon the "White collection," for the use of which the writer is under the greatest of obligations to Prof. I. C. Russell of the University of Michigan, who has most generously loaned the Kinderhook portion of the collection for study. The specimens in the "White collection" are, for the most part, each marked with the number of the bed from which they were collected, but even without these numbers one is able to recognize by its lithological characters alone the bed from which each specimen is derived. In addition to the "White collection" Prof. Samuel Calvin has kindly loaned such material as he possessed, and Prof. J. A. Udden has furnished a small collection from bed No. 1. The collections made in the field by the writer have also added information as to the stratigraphic position of some species.

In the following lists, all the species which have been recognized in each bed, will be given, with such notes on the species and on the faunal assemblages of species, as may seem necessary.

Bed No. 1.—At the time the investigations of the Kinderhook faunas at Burlington were being carried on by Dr. White, no fossils had been found in this bed, and until recently it has

been supposed to be entirely unfossiliferous. Since the opening of the clay pits of the Granite Brick Co., however, many fossils have been found at this horizon and the fauna is a most interesting assemblage of species. The fauna has not yet been critically studied, however, and as many of the species are as yet undescribed, it will, in most cases, be possible to refer them only to their proper genus. For the material illustrating this fauna, the writer is indebted entirely to Professor Calvin and Professor Udden.

SPONGIAE—

1. *Dictyophyton* sp. undet. A single specimen of a sponge belonging to the *Dictyospongidæ* has been observed. It is too imperfect for identification.

CRINOIDEA—

2. Crinoid stems. Not common.

BRACHIOPODA—

3. *Lingula* sp. undet.
4. *Orbiculoidea* sp. undet.
5. *Schizophoria* sp. undet. This is possibly an undescribed species allied to the *S. striatula* or *S. swallovi*.
6. *Rhipidomella* sp. cf. *R. burlingtonensis* H.
7. *Productella* sp. undet. This is a species closely allied to some of the Devonian forms.
8. *Productus* sp. undet. This a species of the *semireticulatus* type and is apparently allied to *P. burlingtonensis* though it may be a distinct species.
9. *Productus laevicostus* White. A single specimen which is seemingly referable to this species has been observed.
10. *Eumetria altirostris* White.

PELECYPODA—

11. *Aviculopecten* sp. undet. This is a large coarsely ribbed species 3½ inches high.

GASTEROPODA—

12. *Platyschisma* sp. undet. A single specimen which possibly belongs to this genus.
13. *Porcellia* sp. undet. This is a large and apparently undescribed species, the largest individual observed being nearly six inches in diameter.

PTEROPODA—

14. *Conularia* sp. undet.

CEPHALOPODA—

15. *Gomphoceras* sp. undet. This species resembles some of the Devonian members of the genus.

CRUSTACEA—

16. *Palaeopalaemon newberryii* Whitf.? This is probably the same crustacean that Whitfield* identified from Kaskade, 3 miles west of Burlington,

*Am. Geol., Vol. 9, p. 237.

Iowa, with his species *P. newberryii*. The species was first described from the Erie shale of Lake county, Ohio, and it is by no means certain that the Burlington specimens are identical with the types of the species or even that they belong to the same genus.

VERTEBRATA—

17. Fish remains. Several fragments of fish bones or spines have been observed.

PLANTS—

18. Fragments of stems and leaves of plants are frequently met with.

The fauna of this bed is a most interesting one, it probably being the oldest of the Kinderhook faunas of the Mississippi valley. The presence of typical forms of the genus *Productus* give to the fauna a strong Carboniferous aspect, the undetermined species of *Productella* and *Gomphoceras* being the only members which are suggestive of the Devonian, unless the fish remains should show some such alliance. The fauna is really more strongly Carboniferous in aspect than is that of bed No. 2, whose large number of pelecypods are for the most part allied to Devonian species in New York. For the satisfactory study of the fauna, however, larger collections than are now available must be secured, and as soon as the necessary material is at hand, this fauna will be made the basis of one number of "Kinderhook Faunal Studies."*

Bed No. 2.†—This bed is the lower one of the two yellow sandstone horizons in the Kinderhook at Burlington, and it contains the most prolific fauna in the section. The fossils are most abundant, in fact are almost wholly restricted to the upper five or six feet of the bed, just below the thin band of impure limestone or bed No. 3. The sandstone is characterized by multitudes of individuals of *Chonopectus fischeri* (N. & P.) and for this reason the bed may be designated as the Chonopectus sandstone. Usually the bed is a soft, friable, yellow grit or fine sandstone, in which the fossils are always preserved as casts, though in many cases the cavities left after the solution of the shell, have been

*Trans. St. Louis Acad Sci., Vol. 9, No. 2, and Ibid, Vol. 10, No. 3.

†For a detailed description of the fauna of this bed, see Kinderhook Faunal Studies II. Fauna of the Chonopectus sandstone at Burlington, Iowa. Trans. St. Louis Acad. Sci., Vol. 10, No. 3, pp. 57-129, plates I-IX.

closed by pressure. At one locality on Flint river, this bed is represented by a highly fossiliferous, much harder, blue sandstone which has weathered along the joints into a soft yellow rock with characters similar to the usual exposures of the formation. From this occurrence it seems possible that the softness and yellow color of the bed as usually exposed, may be due to a weathered condition, but this could only be determined by extensive excavations.

The following list of species found in the Chonopectus sandstone is probably not absolutely complete and additional species will probably be discovered:

CRINOIDEA—

1. Joints of crinoid stems.

VERMES—

2. Worm burrows.

BRACHIOPODA—

3. *Lingula membranacea* Win.
4. *Orbiculoidea capax* (White.)
5. *Orthothetes inaequalis* (Hall).
6. *Schizophoria swallowi* (Hall).
7. *Chonetes illinoisensis* Worthen.
8. *Chonetes* sp. cf. *C. geniculata* White.
9. *Chonetes* sp. undet.
10. *Chonopectus fischeri* (N. & P.).
11. *Productus semireticulatus* Martin.
12. *Productus cooperensis* Swall?.
13. *Productus laevicostus* White.
14. *Productella nummularis* (Win.).
15. *Pugnax striatocostata* (M. & W.) var.?
16. *Rhynchonella* sp. undet.
17. *Eumetria altirostris* (White).
18. *Athyris corpulenta* (Win.).
19. *Spirifer subrotundatus* Hall.
20. *Spirifer biplicatus* Hall.
21. *Syringothyris extenuatus* (Hall).
22. *Reticularia cooperensis* (Swal).

BRYOZOA—

23. *Fenestella* sp. undet.

PELECYPODA—

24. *Aviculopecten tenuicostus* Win.
25. *Aviculopecten caroli* Win.
26. *Pterinopecten* cf. *P. laetus* Hall.
27. *Pernopecten?* sp. undet.
28. *Leiopteria spinalata* (Win.).
29. *Avicula strigosa* (White).

30. *Pteronites whitei* (Win.).
31. *Mytilarca occidentalis* (W. & W.).
32. *Mytilarca fibristriata* (W. & W.).
33. *Goniophora jennæ* (Win.).
34. *Macrodon cochlearis* Win.
35. *Macrodon modesta* (Win.).
36. *Grammysia plena* Hall.
37. *Grammysia amygdalinus* (Win.).
38. *Edmondia burlingtonensis* W. & W.
39. *Edmondia quadrata* (W. & W.).
40. *Edmondia aequimarginalis* Win.
41. *Edmondia nitida* Win.
42. *Edmondia jejunus* (Win.).
43. *Sphenotus rigidus* (W. & W.).
44. *Sphenotus bicarinatus* (Win.).
45. *Sphenotus iowensis* (Win.).
46. *Sphenotus bicostatus* Weller.
47. *Spathella ventricosa* (W. & W.)
48. *Cardiopsis megambonata* Win.
49. *Schizodus iowensis* We'ler.
50. *Schizodus burlingtonensis* Weller.
51. *Cypricardinia sulcifera* (Win.).
52. *Glossites elliptica* (Win.).
53. *Glossites? burlingtonensis* Weller.
54. *Promacrus cuneatus* Hall.
55. *Posidonomya? ambigua* Win.

GASTEROPODA—

56. *Loxonema shumardana* (Win.).
57. *Loxonema oligospira* Win.
58. *Loxonema* sp. undet.
59. *Murchisonia quadricincta* Win.
60. *Strophostylus bivolve* (W & W.).
61. *Sphaerodoma pinguis* (Win.).
62. *Naticopsis depressa* Win.
63. *Straparollus macromphalus* Win.
64. *Straparollus ammon* (W. & W.).
65. *Straparollus angularis* Weller.
66. *Platyschisma barrisi* (Win.).
67. *Platyschisma depressa* Weller.
68. *Phanerotinus paradoxus* Win.
69. *Bellerophon bilabiatus* W. & W.
70. *Bellerophon vinculatus* W. &. W.
71. *Bellerophon panneus* White?
72. *Bucanopsis deflectus* Weller.
73. *Patellostium scriptiferus* (White).
74. *Porcellia crassinoda* W. &. W.
75. *Porcellia obliquinoda* White.
76. *Porcellia rectinoda* Win.
77. *Dentalium grandaevum* Win.

PTEROPODA—

78. *Conularia byblis* White.

CEPHALOPODA—

79. *Orthoceras whitei* Win.
80. *Orthoceras heterocinctum* Win.
81. *Orthoceras indianense* Hall.
82. *Phragmoceras expansum* Win.
83. *Cyrtoceras unicorne* Win.
84. *Agoniatites opimus* (W. & W.).

In some particulars this fauna of the Chonopectus sandstone exhibits strongly Devonian characteristics, but associated with this Devonian element there is another element of perhaps greater significance binding it to the Carboniferous. Of all the genera and species, the brachiopods are for the most part strongly Carboniferous in aspect. The abundance of *Productus* is particularly a Carboniferous characteristic of the fauna, as is also the presence of *Syringothyris*. Of the two species of *Spirifer* one, *S. subrotundatus*, with its completely plicated shell and with the plications on the lateral slopes bifurcating, is strongly Carboniferous in aspect, while *S. biplicatus*, on the other hand, with its excessively elongate hinge-line, has just as strong a Devonian aspect. The presence of *Productella* may be considered as a Devonian element, and also *Orthothetes inaequalis*, which is so nearly like *O. chemungensis*.

The pelecypods have quite a different story to tell, and from a study of this portion of the fauna alone, one would, perhaps, be justified in identifiying it as of Devonian age. All of the nineteen genera, with the exception of two, *Promacrus* and *Avicula*, have numerous representatives in the Devonian faunas of eastern North America, particularly in the Chemung faunas of New York and Pennsylvania, and several of the genera have no representation later than the Kinderhook. *Promacrus* is a genus which is represented in America only in the Kinderhook, and in Europe it has been noted only in Belgium from near the base of the Carboniferous. *Avicula* is in general a later genus. Not only are most of the pelecypod genera abundantly represented in the Devonian, but in

several instances the species in the Chonopectus sandstone are so nearly like species in the Chemung of New York, that it is largely a matter of personal opinion as to whether they are really distinct or not.

The gasteropods and cephalopods are also for the most part of Devonian types, with no strikingly Carboniferous characteristics. The genus *Agoniatites* has not previously been recognized outside the Devonian, and *Orthoceras whitei* is a very ancient type, being related to the Silurian *O. annulatum*.

Taken as a whole, a larger number of the species recognized in the fauna have Devonian and not Carboniferous relationships, but this is not sufficient evidence upon which to establish the Devonian age of the fauna. In general, in paleontologic interpretation, the initiation of a new invertebrate faunal element is of greater importance than the holding over of a much larger element from an older fauna, and on this principle, the strongly Carboniferous element among the brachiopods of the Chonopectus sandstone, is to be considered as weightier evidence than the hold-over pelecypods and cephalopods.

In any study of the Kinderhook faunas it must always be kept in mind that they are on the border line between the Devonian and Carboniferous, where a mingling of the two faunas and a gradual transition from the one to the other may be looked for.

Bed No. 3.—This bed consists of two quite different parts, one of which is constantly present and another which is often absent. The persistent bed is a hard, impure limestone composed almost exclusively of individuals of a single small species of *Chonetes*, all other fossils being rare and but a small number of species being present at all. The following is a list of the species which have been recognized:

BRACHIOPODA—

1. *Orthothetes* cf. *O. inaequalis* (Hall).
2. *Rhipidomella burlingtonensis* (Hall).
3. *Chonetes* sp. cf. *C. geniculata* White.
4. *Chonopectus fischeri* (N. & P.).

In some places, there lies above this Chonetes bed an oolitic limestone layer, which if it were persistent would be deserving of separate recognition. White did recognize it as a distinct member in his section. It has a thickness of but about three inches and is always associated with the Chonetes bed, and for these reasons the two beds have been placed together in this paper, although no species of fossils have been observed to be common to both. The following species have been recognized from this oolite, all the specimens being preserved in the "White collection":

PELECYPODA—

1. *Aviculopecten iowensis* Miller.
2. *Microdon leptogaster* Win.

GASTEROPODA—

3. *Holopea subconica* Win.
4. *Holopella mira* Win.

Bed No. 4.—This bed is a fine-grained, compact, brittle, gray limestone with a conchoidal fracture. In its outcrops it is always fragmental, being broken into irregularly shaped masses which rarely have any dimension greater than six inches. In its lithologic characters this limestone has the appearance of a lithographic stone, and is in this particular almost identical with the Louisiana limestone at Louisiana, Missouri. Judging from the lithologic characters alone, one would be entirely justified in considering this bed as a northern extension of the Louisiana limestone.

The fauna of the bed is not a prolific one so that no entirely satisfactory comparison between it and the fauna of the Louisiana limestone can be made. The species of *Syringothyris* in this bed at Burlington, which has been named *S. halli* by Winchell, seems to be identical with *S. hannibalensis* (Swallow) from Louisiana, the only conspicuous difference being in size, the Burlington specimens being much smaller than those from Louisiana. None of the remaining species at Burlington have been recognized at Louisiana. The following species have been identified:

BRACHIOPODA—

1. *Chonopectus fischeri* (N. & P.).
2. *Rhynchonella heteropsis* Win.
3. *Rhynchonella unica* Win.
4. *Rhynchopora pustulosa* (White).
5. *Pugnax striaticostata* (M. & W.).
6. *Syringothyris halli* Win.

Bed No. 5.—In its upper portion, bed No. 4 becomes more and more arenaceous until it merges somewhat gradually into the upper "yellow sandstone" which constitutes bed No. 5. In the transition layers between the well defined limestone below and the yellow sandstone above, no fossils have been observed, but in the sandstone itself fossils are sometimes extremely abundant. The fauna is quite distinct from that of the Chonopectus sandstone below, only two species being common to the two beds. The fossils from this upper sandstone may be always recognized by their condition of preservation and by the character of the sediment, this sandstone being denser and of a lighter color than that below. In both beds the fossils are always in the form of casts, but in the lower formation the cavities left by the solution of the calcareous matter of the shells and other fossils, have usually been closed by pressure, while in the upper sandstone the cavities remain open. In size the species occurring in this upper sandstone contrast somewhat strongly with those below, a large proportion of the species being diminutive.

The following species have been recognized in the fauna of this bed:

BRACHIOPODA—

1. *Leptaena rhomboidalis* (Wilck).
2. *Orthothetes inaequalis* (Hall).
3. *Productus arcuatus* Hall.
4. *Productus parvulus* Win.
5. *Productus morbillianus* Win.
6. *Camarophorella lenticularis* (W. &. W.).
7. *Dielasma allei* (Win)
8. *Spirifer marionensis* Shum.
9. *Spirifer centronatus* Win.
10. *Spirifer* sp. undet.
11. *Reticularia cooperensis* (Swall).
12. *Cyrtina acutirostris* (Shum.)?

PELECYPODA—

13. *Pterinopecten nodocostus* (W. & W.).
14. *Pernopecten cooperensis* (Shum.).
15. *Lithophaga* sp. undet.
16. *Macrodon parvus* W. & W.
17. *Edmondia nuptialis* Win.
18. *Edmondia strigillata* Win.
19. *Sphenotus cylindricus* (Win.).
20. *Spathella phaselia* Win.
21. *Nucula iowensis* W. & W.
22. *Palaeoneilo microdonta* (Win.).
23. *Palaeoneilo barrisi* (W. & W.).
24. *Leda saccata* (Win.).
25. *Dexiobia ovata* (Hall).
26. *Dexiobia halli* Win.
27. *Schizodus trigonalis* (Win.).

GASTEROPODA—

28. *Straparollus angularis* Weller.
29. *Straparollus* sp. undet.
30. *Bellerophon* sp. undet.
31. *Bucanopsis perelegans* (W. & W.).
32. *Dentalium grandaevum* Win.

In this fauna *Spirifer marionensis* and *Cyrtina acutirostris*, two species which are particularly abundant in the Louisiana limestone, make their first appearance in the Burlington section. *Spirifer marionensis* becomes much more abundant in the succeeding oolite bed, but *Cyrtina acutirostris* has not been observed elsewhere in the section. The brachiopod element in the fauna is predominantly Carboniferous in aspect, but the pelecypods still continue to exhibit Devonian affinities in such genera as *Pterinopecten* and *Palaeoneilo*, though this more ancient element in the fauna is far less conspicuous than in the Chonopectus sandstone fauna.

Bed No. 6.—Succeeding the upper yellow sandstone, there is a conspicuous bed of white oolitic limestone which is quite sharply defined both below and above. Fossils are abundant and are often most beautifully preserved. The following species have been observed:

CORALS—

1. *Zaphrentis* sp. undet.

BRACHIOPODA—

2. *Leptaena rhomboidalis* (Wilck).
3. *Orthothetes inflatus* (W. & W.).

4. *Chonetes logani* N. & P.
5. *Chonetes illinoisensis* Worthen.
6. *Productus arcuatus* Hall.
7. *Productella concentricus* Hall.
8. *Schizophoria subelliptica* (W. & W.).
9. *Rhipidomella* sp. undet.
10. *Dielasma allei* (Win.).
11. *Spirifer marionensis* Shum.
12. *Athyris crassicardinalis* White.

PELECYPODA—

13. *Pernopecten circulus* (Hall).
14. *Conocardium pulchellum* W. &. W.

GASTEROPODA—

15. *Straparollus obtusus* Hall.
16. *Pleurotomaria quinquesulcata* Win.
17. *Loxonema* sp. undet.
18. *Capulus* sp. undet.

CEPHALOPODA—

19. *Orthoceras indianensis* Hall.
20. *Gyroceras burlingtonensis* Owen.

In this fauna of the oolitic limestone the Devonian elements have practically disappeared.

Bed No. 7.—The topmost bed of the Kinderhook at Burlington, immediately beneath the Burlington limestone, is a brown, porous, magnesian limestone. Fossils are not abundant and those that are present are usually more or less imperfectly preserved. The following species have been observed:

CORALS—

1. *Leptopora typa* Win.

BRACHIOPODA—

2. *Orthothetes inflatus* (W. & W.).
3. *Orthothetes inaequalis* (Hall)?
4. *Productus punctatus* Martin.
5. *Camarophoria caput-testudinis* (White).
6. *Rhynchonella persinuata* Win.
7. *Spiriferina solidirostris* (White).
8. *Nucleospira barrisi* White.

GASTEROPODA—

9. *Bellerophon pannens* White.
10. *Pleurotomaria mississippiensis* W. & W.
11. *Igoceras undata* (Win.).
12. *Capulus paralius* W. & W.
13. *Capulus vomerium* (Win.).

Conclusion.—The study of the Kinderhook faunas at Burlington has brought out quite strongly several important facts.

First.—The "yellow sandstone" fauna of authors includes in reality two quite distinct faunas which occur in two entirely distinct yellow sandstone formations separated by a well defined limestone bed.

Second.—The Kinderhook series at Burlington represents a much longer time period than does the series of strata referred to this epoch elsewere, the lower beds being older than the Louisiana limestone which is placed at the base of the Kinderhook in Missouri.

Third.—Beds No. 1, No. 2, and No. 3 are pre-Louisianan in age, the earliest indication of the Louisiana limestone fauna being found in bed No. 4 which may be considered, with a fair degree of certainty, as the northern extension of the Louisiana limestone.

Fourth.—The succession of faunas exhibits a somewhat gradual transition from the earlier faunas with quite marked Devonian characters, to the later ones which are typically Carboniferous in aspect. The Devonian element in the faunas is for the most part exhibited by the pelecypods while the brachiopods are usually Carboniferous in aspect. This overlapping and intermingling of Devonian and Carboniferous faunal elements, makes it impossible to draw a sharp line separating the Devonian and Carboniferous systems such as is recognized in the continental interior between the Ordovician and Silurian in the Medina formation, and between the Silurian and Devonian in the Waterlime formation. The Devonian-Carboniferous dividing line is more nearly analagous with the Cambrian-Ordovician division.

GEOLOGY OF

LYON AND SIOUX COUNTIES.

BY

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INTRODUCTION.

SITUATION AND AREA.

Lyon county lies in extreme northwestern Iowa, the state line forming its northern boundary, while the Big Sioux, which here marks the line between Iowa and South Dakota, bounds it on the west. It includes eighteen townships, the northern tier containing thirty square miles each, instead of the normal thirty-six. Its total area is 704 square miles. Sioux county lies directly south of Lyon. It includes twenty-two townships with an area of 768 square miles, those townships along the Big Sioux river being irregular. Both counties are highly favored by nature in soil and climate. Opportunities for agriculture so exceptional have not been overlooked and the entire area is under cultivation. There is no waste land in either county.

PREVIOUS GEOLOGICAL STUDY.

The nature and age of the quartzite in South Dakota, Minnesota, and Iowa have long interested students of geology. The exposures north of Iowa were more generally studied, since they are more conspicuous than the Iowa outcrops. Catlin and Nicollet* were chiefly interested in the quartzite because it was associated with the pipestone of the Indians. In 1865 James Hall made certain deductions in regard to its age from observations in southwestern Minnesota. Hayden examined outcrops in southeastern Dakota and visited the pipestone quarries farther north. In the following year, 1867, White traveled up the Big Sioux from Sioux City and appears to have called attention for the first time to the quartzite exposures in Iowa. Kloos and Winchell, in Minnesota, have each added to our knowledge of the formation, while Upham and Todd have reported valuable observations in South

*For bibliography of Sioux quartzite, see Iowa Acad. Sciences, Vol. 11, p. 218.

Dakota. Keyes, in Iowa, has contributed material to the rapidly-growing literature on the quartzite.

In addition to the quartzite other geological features of the region have received some attention. A general description of the surface features of Lyon county was written by C. A. White for the Iowa Geological Survey, and is found in Vol. II (1870) pp. 77-95. The Hull well has attracted some attention and the records of the strata passed through have been studied by Keyes, Beyer, and Norton. Exposures near Hawarden have been studied by Bain and were reported by him in connection with Cretaceous deposits of Plymouth county.* Todd has examined and reported on certain cuttings east of Canton, while his work in the adjacent territory of South Dakota throws light on many problems across the river in Iowa.†

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface of Lyon and Sioux counties presents a plain broken by the erosion of streams, with a slight slope to the southwest. The following table illustrates fairly the surface inequalities of the region. It hardly gives an idea of the slope that would prevail if the river valleys were eliminated, since many of the elevations cited are those of towns located on the larger streams. The towns mentioned in the table are arranged in four series representing approximately east and west lines, the distance between the first, second, and third averaging fifteen miles, while the fourth is within six miles of the third. All of the towns mentioned lie within the counties under consideration except Ellsworth, which is north of the Iowa line one mile, and Struble and Sheldon, which are an equal distance south and east respectively of the Sioux county line:

The towns in italics are valley towns and their elevation is affected to a greater or less extent by this fact. Lester is in the valley of Mud creek; Rock Rapids, Doon, Little Rock and Rock Valley are in the proximity of Rock river; the elevations of Sheldon, Alton, Hosper, and Carnes are affected by their

*Iowa Geol. Survey, Vol. VIII, p. 332.

†Iowa Acad. Sciences, Vol. VI, p 132.

nearness to the East Floyd, while those of Maurice and Struble

NORTH.

	Granite 1310	Larchwood 1465	*Lester* 1377	*Rock Rapids* 1345	Ellsworth 1445	*Little Rock* 1475	
WEST.	*Beloit* 1240	Inwood 1471	*Doon* 1285 *Rock Valley* 1253	Hull 1433	Boyden 1423	*Sheldon* 1415	EAST.
	Hawarden 1188	Ireton 1377	*Maurice* 1314	Orange City 1421	*Alton* 1308	*Hosper* 1341	
	Chatsworth 1152		*Struble* 1271		*Carnes* 1261		

SOUTH.

are influenced by the West Floyd. All of the towns in the western tier are near the Big Sioux:

NORTH.

	1 mile S of Granite 1440	Larchwood 1465		2 miles E of Rock R'pids 1415	Ellsworth 1445	1 mile W of Little Rock 1505	
WEST.		Inwood 1471	3 miles E of Rock Valley 1323	Hull 1433	Boyden 1423	1 mile W of Sheldon 1475	EAST.
	2 m N E of Chatsworth 1252	Ireton 1377	3 miles E of Maurice 1395	Orange City 1421			

SOUTH.

The second table gives upland elevations only and bears out the statement that the normal slope is from northeast to southwest, and slight.

Topography of older drift.—The surface of this slightly sloping plain has been sufficiently diversified by stream erosion to afford perfect drainage, which with the nature of the soil results in an ideal farming region. The slopes are gradual, indicating for the streams a considerable age, and the bottom lands are broad, seldom deeply cut by recent stream beds,

making it possible in most cases to cultivate the soil to the water's edge. From fifteen to twenty feet above the flood plain in the valleys of the Big Sioux and Rock rivers there is a conspicuous terrace, generally much broader than the flood plain. The soft nature of the material through which the streams have cut favors the formation of broad shallow valleys. The major stream of the region, the Big Sioux, forms the western boundary of the two counties under consideration. During this short course of forty-two miles its valley changes materially in nature and size. From the state line at the north to Elm Springs, the valley is admirably set forth by the portion of the United States topographic map for the Canton district that accompanies this report. On the Dakota side for four miles south of the state line high bluffs face the river. Continuing south on the same side for ten miles, till a point three miles south of Canton is reached, there are no bluffs, and the gravel terrace is but a few feet below the average level of the region. At this point very prominent bluffs again appear and continue nearly to Hudson. The bluff topography continues to the south, but after passing Hudson they recede from the river, forming bold headlands only here and there where the river has very recently been cutting at their base. On the Iowa side these pronounced bluffs, averaging 150 feet above the river, do not appear north of Blood Run creek, which empties into the Big Sioux three miles below the state line. Beginning at this point they continue without a break as far south as Hudson, where the topographic features become uniform for both sides of the river. For seven miles north of Canton, therefore, the Iowa bluffs overlook the Dakota plain which lies 150 feet below.

The width of the valley varies in the same way. At the state line it is two miles across, and so continues to the mouth of Blood Run creek. Thence to Canton it is often not more than half a mile wide, its upper course appearing narrower on account of the bluffs. From Canton to Beloit it is again two miles wide. A mile below Beloit it narrows sharply to half a

mile and this width persists to the mouth of the Rock river above Hudson. From Hudson to Chatsworth its average width is two miles.

The bottom lands of the Rock river near its mouth are half a mile wide and so continue as far as Doon. The river here divides into the East and West Rock, and the valley of each is proportionately less than that of the stream after their junction. Six Mile creek, on some maps called Ford creek, flows through a valley of some maturity. Ten miles from the mouth of the stream the bottom lands are 200 feet across and lie seventy feet below the upland plain, from which the slope is very gradual. Mud creek is a tributary of the East Rock, into which it empties near Doon. It barely reaches across Lyon county into Minnesota, and drains in its course the greater part of three townships. Its valley is broad, however, broader than the present size of the stream would justify apparently, and an explanation is suggested in connection with other problems of the Pleistocene. The valley of the West Floyd in Sioux county, also, is out of proportion to the present size of the stream. This opinion is reached by comparing it with other valleys in these counties that seem to be of the same age in other respects. Although it rises two miles north of Boyden, in Tp. 96 N., R. XLIV W., Secs. 4 and 8, in Sioux county its valley is two miles wide and sixty feet deep. This extensive valley in the vicinity of Middleburg is indicated on the railroad commissioners' map as a slough. In the neighborhood it is known as Belle lake, though the term lake seems never to have been applicable. In former years the river overflowed this broad bottom land during the spring, but of late the land has been under cultivation. No artificial drainage has brought about the change but the washing down of the slopes has filled in the lowlands. These slopes have been under cultivation for thirty years and the loess surface under these conditions readily washes into the hollows. There are no sloughs or lakes in either county and a topographic map of the region would make clear the fact that the entire area is reached by the streams and none left undrained. The

minor feeders are not conspicuous enough to be placed on an ordinary map, and only during the rainy seasons do they appear as water courses. In the spring, however, great quantities of water pour down the broad valleys that everywhere open into the main creek and river beds, testing and sometimes overstraining the capacity of the culverts which, as a rule, are unusually large. The surface of the region, therefore, is decidedly undulatory. Except along the Big Sioux there are no sharp ravines with steep sides, but instead there are gradual slopes from a broad crest leading to a broad valley. To gain one crest, however, is simply to discover another hollow. The grades are not steep, they may usually be climbed with a bicycle, and the long even declines make it possible to coast to the bottom of the depression and part way up the next slope.

The topographic map of the Canton quadrangle takes in enough of western Lyon county to bring out the contrast between this surface and the Wisconsin drift of Dakota. At a glance it reveals the fact that the Lyon county surface is older and its drainage more perfectly developed. This difference would be more marked had a section of Lyon, or Sioux county away from the Big Sioux been taken for comparison, for certain factors to be considered later have made the region along the Big Sioux somewhat abnormal. Notably so is the strip from Canton to the mouth of Rock river. Attention has already been called to the bluffs along the river at this point. The streams flowing into the Big Sioux here are insignificant in length, and instead of valleys they flow through narrow sharp angled ravines commonly termed draws. Their sides are precipitous and wagon roads are made with difficulty.

Topography of Wisconsin moraine and outwash.—Another region with abnormal topography includes certain parts of four townships in northeastern Lyon county. In following the road on the state line toward the east, at Tp. 100 N., R. XLIV W., Sec. 10 center, the undulations that characterize the country to the west will be found to cease and for four

miles a conspicuously level surface prevails. The western edge of this level area is not clearly defined, yet the changes in conditions will be noticed within half a mile. The inner or eastern edge is bounded by a distinct ridge having an elevation of fifty feet. This ridge trends from southeast to northwest, crossing the state line at Tp. 100 N., R. XLIII W., Sec. 8, eastern edge. Four miles southeast, at Little Rock, it loses its distinctness on account of the erosive action of the East Rock river. Within this ridge, that is, to the north and east, the country is rolling, the ridges in general having the same direction as the outer one. They are more persistent than the ridges formed by erosion found elsewhere in the county, and cutting into them there are no secondary ravines. The East Rock river north of the town of Little Rock flows between two of these ridges in a trough that might readily be mistaken for a valley that the stream has created. The size of the trough, however, is out of proportion to the valley of the stream a little farther south. Here and there within this region of ridges are hummocks of sand and gravel reaching an elevation of sixty feet. These are most conspicuous in Tp. 100 N., R. XLIII W., Secs. 15 and 23. These conditions, namely, a broad level belt fringing a ridge on the inside of which are other ridges having a similar trend, persist to the north and were easily traced as far as Adrian, Minn., and to the southeast into Osceola county.

DRAINAGE.

The rivers of Lyon and Sioux counties are tributaries of the Missouri. The Big Sioux forms the western boundary of these counties and with its branches drains all of Lyon county and the western half of Sioux. Its source is in Dakota some forty miles north of the boundary of Iowa. Between the mouth of Rock river and the Dakota line the Sioux receives few tributaries, Blood Run and Plum creeks being the largest. The elevation of low water at Brandon, South Dakota, which is below the falls and near the state line, is 1281 feet, while at Chatsworth, near the southern Sioux county line, it is 1132

feet; giving a total fall of 149 feet and an average fall of 3.2 feet per mile. This fact makes the stream valuable for water power. At Hawarden and Hudson dams which give a head of seven feet cause the water to set back only two miles.

Rock river is the largest tributary of the Big Sioux and, with its branches, drains northeastern Sioux county and central and eastern Lyon county. Three miles south of Hudson it unites with the Big Sioux. Its elevation here is 1195 feet, while at Rock Rapids its low water level is 1450 feet above the sea, making for the intervening distance a descent of 265 feet, or 5.3 feet per mile. Near Doon it receives as tributaries Mud creek and East Rock river. Kanaranzi and Tom creeks unite with it near Rock Rapids.

Six mile creek empties into the Big Sioux at Chatsworth. It is twenty miles long and drains fifty square miles in southwestern Sioux county. Dry creek, which flows into the Big Sioux at Hawarden, drains an equal area. Both of these streams are insignificant and often quite without water in summer, but during periods of rain, on account of the slope and their elaborate system of feeders, they suddenly assume considerable proportions. Western and central Sioux county is drained by the East and West Floyd. In Sioux county the characteristics of these streams are those of Six Mile creek just described. They have a fall of about five feet per mile.

Of these streams the Big Sioux is the only one that has a valley in which are exposed the indurated rocks that underlie the drift. The age of the stream, therefore, is best considered in connection with the age of the drift and other phenomena of the Pleistocene.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

The formations of Lyon and Sioux counties may be grouped in two classes primarily; those in which the component substances are heterogeneous, and those which are practically

uniform in nature. Under the first may be included the glacial drifts and associated deposits. In the drift the rock fragments vary greatly in composition and origin, having been picked up by the ice sheets from the various regions over which they passed. The only deposits related to the drift that approach homogeneity are certain outwash beds of sand, and the loess, though the glacial origin of the latter may be fairly questioned.

Beneath these glacial deposits are formations that in structure and composition are nearly uniform. Between these homogeneous formations and those which vary greatly in composition and structure are certain sands and clays that are not readily classified. The difficulty arises from the fact that these sands and gravels are quite uniform in the few places where found, but exposures are so rare that they may possibly belong to the upper heterogeneous series which, for a very limited area, fails to present its normally diversified characteristics.

Aside from the Sioux quartzite in northwestern Lyon county the only opportunity for directly observing the indurated rocks that everywhere underlie the drift is given by exposures along the Big Sioux river. A limited amount of information may be gained from records of well borings. The Sioux quartzite, which is generally regarded as Huronian, is the oldest rock formation in these counties. Other strata beneath the drift belong to the Cretaceous, except certain sands and clays which are probably to be referred to the Pliocene. The classification of known strata is shown in the following table:

In western Iowa, eastern Nebraska, and eastern Kansas the Cretaceous strata rest directly on the Carboniferous.* Farther west, in the Rocky mountains, the whole Jura-Trias series intervenes. The conclusion follows that at the end of the Carboniferous age the shore line was far to the west of Iowa and that the Carboniferous rocks in the western part of the state were subject to erosion for a very long period of time.

*U. S. Geol. Survey, bulletins, Vol. IV, p. 870.

At the end of this period there was a subsidence that brought the shore line again eastward as far as central Iowa. While this subsidence was going on the Cretaceous deposits were formed. During the first stages of the subsidence, along the

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.	FORMATION.
Cenozoic.	Pleistocene	Recent.			Alluvium.
		Glacial.	Wisconsin.		Moraines Gravel trains.
			Iowan?		Loess.
			Kansan.		Drift.
	Pliocene?				Sands and clays
Mesozoic.	Cretaceous	Upper.	Colorado.	Benton.	Shales.
			Dakota.		
Eozoic.	Algonkian.				Quartzite.

gradually retreating shore line, sands were deposited which now appear as the Dakota sandstone, the lowest member of the Cretaceous in northern Iowa. Later, when the depth of the water had increased, the Colorado shales and limestones were laid down above these sands. At the close of the Colorado stage the region was again raised above water, with the possible exception of certain limited areas that were lake beds during Tertiary times.

ALGONKIAN.

THE. QUARTZITE.

The Sioux quartzite or "granite," as it is commonly called, appears on the surface in a single township in Lyon county. The area in Minnesota and Dakota, however, within which exposures of this rock are common, is considerable. As stated

by Beyer* its extreme eastern limit of outcrop is found at Redstone, and its most westerly exposure is near Mitchell on the James river. Its greatest width is about sixty miles, extending from Flandreau on the north, to Canton, which is on its southern border, giving a total area of more than 6,000 miles. Its thickness has been variously estimated, but on this point there is little on which to base a positive assertion. Well drillings have not passed through it, though they have entered it to a considerable depth, and there are no great folds or flexures. It is thought by Todd of the South Dakota survey† and by Beyer that its thickness does not exceed 1,500 feet.

Instead of quartzite, originally the formation was water-laid sand. Proofs are still present in the ripple marks and lines of lamination and stratification. The layers varied in thickness from two feet to half an inch. Cross bedding was not uncommon, indicating that, in places at least, the sand was deposited by rapidly running water. These characteristics are still preserved in the quartzite. Subsequently the sand was permeated by water holding in solution silica which crystallized around the sand grains and cemeted them together, producing a solid quartz mass. Microscopic study of the quartzite by Irving and Van Hise has made clear the fact that the silica which forms the matrix has been deposited along lines that correspond with the crystalline axes of the several grains. The interstitial deposit of silica explains the unusual firmness of the rock. The same observers made clear that while silica was deposited about all of the sand particles, frequently the quantity was not sufficient to fill all of the spaces between the grains. As a result a sandstone easily crumbled was produced. Throughout the quartzite this condition exists. In close proximity to quartzite and in the same beds the rock shades off into friable sandstone and even into uncemented sand. These softer layers are generally thin and quickly give place to the normal quartzite

*Iowa Geological Survey, Vol. VI, p. 71.
†Preliminary Report on Geol., S. Dak., 1894, p. 35.

Well drillings that have penetrated the quartzite show that in the midst of the harder rock there are at times several feet of sand. An example of this sort is found in the well of the B., C. R. & N. railroad at Ellsworth, Minn., one mile north of the Lyon county line, where the quartzite was encountered under 180 feet of drift and fifty feet of shale. It was penetrated to a depth of 315 feet, and frequently sand layers of considerable thickness were found. The color of the rock varies from pink to purple, red being most prevalent. The coloring matter is oxide of iron, which forms a thin coating around the quartz grains. Near the upper surface and along joints leaching has evidently taken place, for the colors are dull. As determined by the Minnesota survey the rock is composed almost wholly of quartz, 85.52 per cent consisting of that mineral.*

The Sioux quartzite is extremely hard, breaks with a conchoidal fracture, and takes a high polish. Catlin wrote of it as follows: "The quartz is of a close grain and exceedingly hard, eliciting the most brilliant sparks from steel, and in most places where its surface is exposed to the sun and air it is highly polished beyond any results that could have been produced by diluvial action, being perfectly glazed as if by ignition."† This polishing is without doubt due to the action of the wind. Excellent examples of this wind polishing are found on "the mound" at Luverne, Minn., and some are found on the Lyon county exposures. The polishing is most marked on vertical surfaces and follows the inequalities of the rock, smoothing out the sharp angles, but not wholly removing the unevenness due to the roughness of the original fracture. It differs, therefore, clearly, from glacial polishing. In the same way quartzite blocks carried by the ice far to the south, when exposed on the surface of the drift, readily become polished. The luster is not unlike that seen on large lumps of rock salt that are constantly licked by cattle. The position of wind polished portions of rock, often

* Geol. and Nat. Hist. Survey of Minn., Vol. I, p. 149.
† Am. Journal of Science, Vol. XXXVIII, p. 145, 1840.

within a few inches of the ground and on vertical surfaces that are protected by projections above, preclude the possibility that the polishing could have been done by animals rubbing against the rock. Winchell, in describing this phenomenon in his discussion of the Quartzite of Rock and Pipestone Counties, Minn.,* says: "The edges of the layers exposed toward the northwest are polished, doubtless by the dust particles swept by winds. The surface in some cases is as smoothly polished as can be done artificially with the utmost skill and patience." Gilbert, in a paper on The Natural Erosion of Sand in the Western Territories,† says that "sand when moved by air in regions where there is no moisture, humus, or vegetation to entangle it, is a denuding agent worthy to be mentioned with frost, wave, and flood." Not only are bold cliffs and the walls of mountain passes eroded by this agency, but pebbles lying in the open plain are carved till their surfaces are ridged and grooved and they are finally reduced to dust. Endlich,‡ considering erosion phenomena in Colorado, comes to the same conclusion. To the writer special interest in this subject of wind polishing was given by the fact that lying on the surface of the drift, but buried by the loess, in Lyon and Sioux counties bowlders were found which appear to have been polished in the same manner as the surface quartzite. They will be considered in connection with the drift and the discussion in regard to the origin of the loess. In the Lyon county quartzite exposures it was observed that polishing does not occur at an elevation above the ground greater than five feet, and that it is most common on vertical surfaces not more than eighteen inches above the level of the soil. This would indicate that small particles carried by the wind, but lifted only a little above the ground, are really the polishing agents.

The dip of the quartzite is variable, so that no series of folds can be made out. It is seldom more than ten degrees. At

* Geol. and Nat. Hist. Survey of Minn., Vol. I, p. 541.
† Proceeding of American Soc. for Adv. Science, Vol. XXIII.
‡ U. S. Geog. Survey of Territories, bulletins, Vol. IV, p. 833.

the mound near Luverne the dip is eight to twelve degrees to the northwest, at Jasper pool in Lyon county it is six degrees north, and at Sioux Falls it is eight degrees south. Todd considers this dip to be that of the original deposition rather than of flexures in the earth's crust.* There are two sets of vertical joint planes, nearly at right angles to each other. They vary in distance from one another from an inch to two feet. These, with the distinct layers, render the rock easy to quarry and at the same time expose it to the agencies that cause disintegration. While it makes the most durable of building materials, as exposed in the beds the action of frosts tends to break the rock into fragments varying in size with the distance between layers and joints. For economic purposes, however, the joints are useful rather than otherwise, since they aid in quarrying, and the distance between them is so variable that solid blocks of any size to suit ordinary purposes are readily obtained.

Age of the quartzite.—Beyer, in the report already referred to,† gives the results of special study in regard to the age of the quartzite and associated formations, and from its lithological character and structural relationships refers it to the Huronian. It has been referred to the Cretaceous by Hayden and to the Potsdam by the geologists of the Minnesota survey. Hall, White, Irving, Van Hise, and Todd favor the Huronian. Keyes,‡ after reviewing the opinions of other authorities, is inclined to think that the great age of these rocks is not to be positively affirmed. Heis led to this opinion by certain fossil forms resembling lamel-libranchs of the Cardium and Cytherea types that he has found in the quartzite, and recalls Hayden's reference to abundant casts in another part of the region. Still, until more light is thrown on the subject, he would regard the quartzite as pre-Cambrian.

The quartz porphyries.—During 1892 a well was sunk at Hull, in Sioux county, for artesian water. At a depth of 755 feet a

*Prelim. Report on Geol., S. Dak., 1894, p. 35.

†Iowa Geol. Survey, Vol. VI.

‡Proceedings Iowa Acad. Sciences, Vol. II, p. 222.

compact olive-green rock was encountered which was mistaken for the Sioux quartzite. More careful study made plain the fact that the drill chips were typical quartz porphyry.* Quoting from Dr. Beyer's report on this well: "After drilling about forty-five feet in quartz-porphyry, a stratum about two feet in thickness of soft fine-grained sandy material was struck. This was immediately followed by another stratum of quartz-porphyry and these in turn gave place to sand-rock. These alternations of quartz-porphyries and sandstones continued to the end of the drilling, a depth of over 1,200 feet. The whole series of quartz-porphyries seem to be identical in structure and composition."

The following is an approximate record of the well below 755 feet:

		FEET.
18.	Compact olive-green quartz-porphyry	755- 800
17.	Fine-grained sandstone	800- 802
16.	Quartz-porphyry	802
15.	Coarse-grained sandstone	825
14.	Quartz-porphyry	832- 840
13.	Fine-grained sandstone	840- 860
12.	Conglomerate	866
11.	Fine-grained sandstone	880- 900
10.	Quartz porphyry	900- 930
9.	Fine-grained sandstone	930
8.	Pebbles and sand	930- 935
7.	Decomposing quartz-porphyry	935- 940
6.	Fresh quartz-porphyry	944
5.	Decomposing quartz-porphyry	949
4.	Quartz-porphyry	975- 990
3.	Sandstone	990
2.	Quartz-porphyry	1,194-1,220
1.	Fine-grained sandstone	1,228

The quartz-porphyries are recognized as of igneous origin, and in this case must represent lava flows of some sort, either overflow beds or intrusive sheets. Beyer's later study of the quartzite and its associated beds led him to interpret the Hull well record as additional evidence of the Huronian age of the quartzite, because the quartz-porphyry "is strikingly similar to the intrusives that are peculiar to the Huronian in the Lake Superior region."

*Iowa Geol. Survey, Vol. I, p. 165.

The quartzite presents many glaciated surfaces. Those on the Lyon county exposures are exceedingly clear and well preserved. Edges that would otherwise be abrupt, are rounded, and surfaces are planed, striated, and in some cases grooved. Chatter marks are common. They are well described by Winchell in his account of the quartzite of Rock county, Minn.*

Fig. 1. Glacial groove on quartzite in Lyon county.

He says: "It cannot be doubted that this marking was done by a force that exerted a great pressure at the same time that the marks were made. This pressure is evinced not only in the marking itself, which is on the hardest formation in the state, but in the minute cross fractures that cover the surface where the rasping has taken place, and yet leave it in the main a smooth and moutoneed surface. These cross fractures run curvingly downward and at varying angles with the surface, and to all depths less than an inch, but usually less than

*Geol. and Nat. Hist. Survey, Minn., Vol. I, p. 548.

one-sixteenth of an inch, and indicate an incipient crushing to the depth of at least an inch. They show in what manner the rasping reduced the original projecting knobs. Where the natural seams or planes of jointage cross the rock, causing the quartzite to chip off sooner and deeper with a curving and conchoidal fracture, these little checks are larger. Their prevailing direction is transverse to the rasping force, so that the rock along some grooves has a short, conchoidally fractured structure transverse to the grooves, penetrating it to the depth of a quarter of an inch, exhibited in a series of little curving furrows where the laminae broke off successively, the convexities of the laminae being toward the north." Knowing the crushing resistance of the quartzite, he has computed that the pressure that caused these marks must have come from an ice sheet several miles in thickness.

THE QUARTZITE IN LYON COUNTY.

On the surface the quartzite is found in but two sections of a single township in Lyon county, and is nowhere exposed in Sioux county. These sections are 7 in Tp. 100, N., R. XLVIII, W. and 11 in Tp. 100, N., R. XLIX W. The first named exposure is found in the north central part of the section and may be seen from the road on the state line. The outcrop is in the bottom of a small valley and is perhaps fifty feet wide, with a total length of half a mile. Erosion has removed the drift over this limited area exposing the quartzite which, doubtless, underlies it throughout this corner of the county. Thirty miles to the east it is known that the Benton shale intervenes. Section 11 of range XLIX is in the bottom lands of the Big Sioux. The quartzite here exposed is in the form of a ridge 100 yards wide and 400 yards long, rising to a height of twenty feet. In the bluffs just across the river an exposure of quartzite, evidently a part of this same ridge, rises to a height of fifty feet.

The dip of the rock at both of the Iowa exposures is six degrees north. Its characteristics are those common to the quartzite in other localities. The metamorphism is general but not universal. Occasionally the rock is soft enough to crumble between the fingers. The joint planes are in two sets

FIG. 2. Jasper Pool. Quartzite exposure in Lyon county.

at right angles to each other and from two to ten inches apart. In section 7 there is a beautiful example of oblique lamination. On the same exposure are remarable glacial striae and grooves. Apparently the drift has but lately been removed from the surface. The maximum depth of the grooves is eight inches, which is considerable when the hardness of the rock is taken into account. There are two distinct sets of striae, one evidently more recent than the other, since in places one is erased by the other. The corrected readings for these striae are S. 30° E. and S. 5° W.* It is not necessary to suppose that they represent two ice sheets. The second set was probably formed by the same ice sheet that was responsible for the first, the change in direction indicating the direction of the ice movement during its recession.

*Allowing 10° for deflection of magnetic needle to the east.

The quartzite, doubtless, underlies both counties, though buried deep by drift and Cretaceous deposits. On Lu Peter's farm near Little Rock, on the eastern boundary of Lyon county, it was encountered beneath shale and drift at a depth of 360 feet. At Ellsworth, Minn., near the northeast corner of Lyon county, it was found beneath similar material at a depth of 281 feet.

FIG. 3. Oblique Lamination in quartzite of Lyon county.

The chief value of the quartzite lies in the fact that it is easily shaped into paving blocks, which, on account of hardness, are practically indestructible. Quarrying for this purpose is extensively carried on at East Sioux Falls, S. Dak. The fragments chipped off in making the blocks can be advantageously crushed for macadamizing. Such a crusher was operated a few years ago at Rowena, S. Dak. Handsome structures for many purposes have been built from the quartzite in the vicinity where it is found, and a considerable quantity has been shipped for building purposes to fairly remote points. There promises to be a steady and

gradually increasing demand for quartzite for all of the purposes mentioned, as its qualities become better known.

CRETACEOUS.

For knowledge of all deposits except the quartzite and drift we are dependent on certain exposures along the Big Sioux and upon well data. Inferences may also be made from exposures in neighboring counties. The Big Sioux has cut through the drift and into the indurated rocks to a total depth of 250 feet, while the deep wells of both counties give data that can be interpreted for 300 feet farther. The following records are those of wells drilled by Mr. M. E. Layne, of Rock Rapids, and are selected from many as typical for the locality in which they occur.

Ellsworth, Minn., railroad well, one mile north Lyon county line:

		FEET.
10.	Soil	2
9.	Yellow clay with gravel	3
8.	Gravel	6
7.	Yellow clay with gravel	80
6.	Sand and gravel (little water)	4
5.	Blue clay with gravel and bowlders	95
4.	Soapstone (shale), blue, no gravel	50
3.	Clean, water-bearing sand	30
2.	Sand, with clay	20
1.	Quartzite at depth of 281 feet	

The flow of water from the sand just above the quartzite in this well is said to be 100,000 gallons in twenty-four hours. An effort was made to pass through the quartzite at this point by other well drillers, and the rock was penetrated 300 feet, when the effort was abandoned.

Well of John Vanderberg, near Sioux Center, in Sioux county, Tp. 96, N. R. XLV W., Sec. 27, south ½:

		FEET.
12	Soil	2
11.	Yellow clay with gravel	150
10.	Loose sand (no water)	4
9.	Blue and yellow clay with bowlders	100
8.	Sand and clay	66
7.	Soapstone (shale), no bowlders or gravel	80
6.	Fine sand (much water), entered to a depth of	13

Well at Hudson, in valley of Big Sioux:

5.	Soil	2
4	Yellow clay with gravel	15
3.	Blue clay with gravel	100
2.	Soapstone (shale), no gravel	145
1.	Sand (much water) stopped in this	

New town well at Hudson, nearer the river than the one just described, on gravel terrace:

		FEET.
6.	Gravel	30
5.	Blue clay with gravel	15
4.	"Soapstone" (shale)	70
3.	Gravel (little water)	3
2.	Shale with pyrites	65
1.	Sand rock with pyrites entered only (much water)	5

Railroad well at Sibley:

		FEET.
7.	Soil	3
6.	Yellow clay with gravel	60
5.	Blue clay with gravel	60
4.	Sand and clay (some water)	6
3.	Blue clay, sand with bowlders	180
2.	"Soapstone" (shale) no gravel	80
1.	Sand with much water, entered only (much water)	20

The capacity of this well is given as 117,000 gallons in twenty-four hours.

Mr. Layne reports that the so-called soapstone is a definite formation and that after reaching it he feels certain of his position and can predict quite accurately the distance beneath it at which he will find the water-bearing sands. He reports the "soapstone" everywhere free from gravel and bowlders. Samples of this rock brought to the surface from his wells show that it agrees in color and texture with certain shales exposed along the Big Sioux. These shales will be carefully considered later. The water-bearing sand in which these wells stop is generally coarse, that brought to the surface from a number of wells resembling that which makes up the Dakota sandstone. The abundance of water that the sand yields favors the belief that they are to be associated with this formation.

DAKOTA SANDSTONE.

In Plymouth county, just south of Sioux, the Dakota sandstone is exposed in cuttings and has been identified not only by its stratigraphical relations but by its fossils as well. There it underlies the Benton shale. It is found in the same position in South Dakota. The shale or "soapstone" of the well records is exposed along the Big Sioux and the fossils that it contains readily show that it is the Benton. Without doubt, then, the sands yielding water in the deep wells cited belong to the Dakota formation.

The Dakota sandstone in South Dakota furnishes the water for the wonderful artesian wells that have added so materially to the wealth of that state. In 1896 the outflow of these wells, as estimated by N. H. Darton, of the U. S. Geological Survey,* was 104,000 gallons per minute. A small fraction of the water is derived from sources other than the Dakota sandstone. The pressure at the surface of these wells is often 100 pounds, and in a few cases amounts to 150 pounds. They supply power for large flouring mills, electric light plants and similar industries. The artesian area lies in the main between the James and Missouri rivers. The increase in elevation west of the Missouri renders artesian wells in this region extremely doubtful, for although the Dakota sandstone with its abundant water underlies it the wells already flowing indicate that the head would not be sufficient to raise the water to the surface. The counties along the Big Sioux in South Dakota and Iowa, however, are very low, 200 feet lower than the artesian district. Regardless of this fact there are no flowing wells in the vicinity of the Big Sioux. The water in the Lyon and Sioux county wells that penetrate the Dakota sandstone rises only to within 100—150 feet of the surface. This lack of pressure necessary to produce a flowing well is accounted for in two ways. First, the Dakota sandstone is exposed along the Big Sioux and the Missouri rivers, and there is opportunity for abundant leakage. A more efficient reason is found in the distance

*U. S. Geol. Survey, 7th An. Rep, p 609.

from the source of supply. The Dakota sandstone outcrops in the Rocky mountains and Black hills, and from these regions the water makes its way eastward through the pervious rock to Iowa. In accordance with the well known law of physics the pressure diminishes regularly as the distance from the source increases. Although the source of the water in the Rocky mountains is 8,000 feet above the Dakota formation in Iowa, the distance readily accounts for the diminished pressure eastward. In considering the underground waters

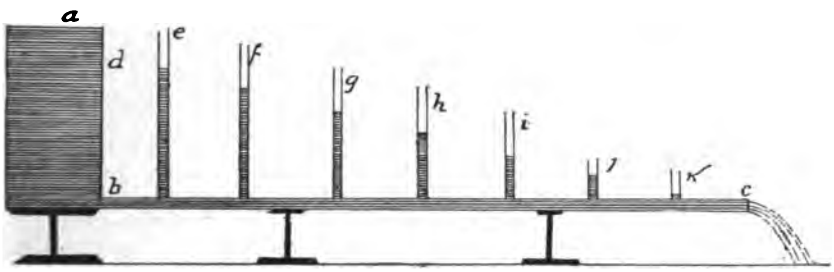


FIG. 4. Diagram illustrating relation of water pressure to distance from source.

of southwestern Nebraska, where the Dakota sandstone furnishes wells like those in Lyon and Sioux counties, Darton† suggests as an additional reason for the limited water pressure, that immediately west the formation may be finer grained and so choke out the water.

THE BENTON SHALES.

Four miles south of Hawarden the Big Sioux river has swung over against its east bank and after cutting through the gravel terrace and drift has made an extensive excavation in the underlying deposits. The Chicago, Milwaukee & St. Paul railroad in laying the bed for its track at this point, has aided geological study by similar excavations. The section thus jointly revealed at one point is as follows:

		FEET.
4.	Loess	5
3.	Drift	2
2.	Shale with selenite	20
1.	Limestone	20

†Irrigation Papers U. S. Geol. Survey, No. 12, p. 47.

Three hundred yards down the river the following series is exposed:

		FEET.
5.	Loess	20
4.	Drift	25
3.	Sand	15
2.	Limestone	20
1.	Shale	10

The exact location of these exposures is in Sioux county, Tp. 94 N., R. XLVIIIW., Sec. 22, west center.

The loess and drift have the characteristics common to these deposits elsewhere in the county. The limestone in both exposures is the same stratum. The lower exposure is on a point of land that projects farther into the valley of the Big Sioux than the upper, and it is evident that the shale which in the upper exposure overlies the limestone, has been removed by erosion and in its place sand deposited. The shale beneath the limestone is probably present at both points but is exposed at only one. The section plainly indicated by these exposures is, then, loess, drift, shale, limestone and shale.

FIG. 5. Benton shale exposed three miles south of Hawarden

The upper shale is everywhere extremely fissile, the laminae averaging ten to the inch, each quite distinct. It is practically free from lime. The predominating color is drab or slate,

though it passes through all shades between red and black. It is everywhere uniformly soft, though it is never reduced to clay. Joints are common, seldom vertical, generally making an angle of 45 degrees with the horizontal laminae. The shale on either side of the joints is oxidized to a rusty red.

In this shale but one fossil form was found. It consists of circular prints about an inch in diameter on the thin slabs of shale. They are the impressions of spiral shells, disc-shaped, the outer volution much larger than those in the center, the volutions ridged.* Three specimens were sent to Professor Calvin, who pronounced them *Prionocyclus wyomingensis*, a member of the Ammonite family.

This shale abounds in selenite. Tabular crystals varying in size from a fraction of an inch to three inches are very common. Generally smaller crystals project from the prismatic faces of the larger ones. Twin crystals are not uncommon. Rosettes often occur, while between the laminae there is a frost work of minute gypsum scales. The larger crystals are seldom clear, all of them apparently containing some impurities.

The limestone that appears in both the upper and lower exposures is in very thin layers, averaging perhaps half an inch. It is clearly distinguished from the upper shale but shades gradually into the lower. It is generally hard and brittle, though at points it is made up of coarse layers and is softer, more nearly resembling chalk rock. At one point there are cracks in the rock sometimes half an inch wide filled with white powder. It effervesces slightly with acid, showing the presence of some lime. When heated it gives off water abundantly. Under the microscope it appears to be made up of very many minute crystals of selenite. The limestone is filled with the large and well preserved shells of *Inoceramus labiatus*.

The shale beneath the limestone is darker, harder and less fissile than that above it. It contains a larger percentage of

*For full description of this ammonite see U. S. Geol. Survey bulletin 106, p. 171.

lime and shades gradually into the limestone. At times the perfectly hard rock gives place to soft clay, which is extremely plastic and in structure and color resembles the fire clay of the coal measures. It is impossible to determine the thickness of this shale here for it extends downward nearly to the water's edge where it is covered with alluvium. From this lower shale rather fragile shells were taken, varying from half an inch to an inch in length, somewhat like clam shells. As identified by Professor Calvin, they belong to the genus Anomia. One specimen of *Ostrea congesta* was found in the same horizon.

The Prianocyclus impressions in the upper shale Professor Calvin regards as sufficient proof that these shales belong to the Benton, for *Prianocyclus wyomingenis* is a characteristic fossil of this group. This precludes the possibility of the underlying Inoceramus limestone stratum being Niobrara. The whole series, namely, upper shale, limestone and lower shale must be regarded as Benton. Professor Calvin reports that just such a series is characteristic of the Benton in the Black hills, where to the limestone stratum the title, "Oyster Shell Rim" is given. Inoceramus specimens from this exposure are of the same type as those of the oyster shell rim in the Black hills, whereas, in the Prianocyclus beds above the rim there is an *Inoceramus labiatus* that has a very different expression, so different that Professor Calvin has

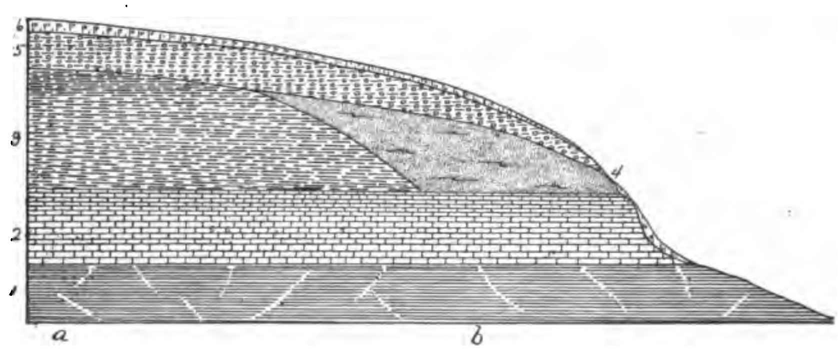


FIG. 6. Section on Big Sioux south of Hawarden. 1. Lower shale. 2. Limestone with *Inoceramus labiatus*. 3. Upper shale. 4. Sand. 5. Drift. 6. Loess.

difficulty in agreeing with writers who do not make it a distinct species.

At the foot of the limestone and in the upper part of the shale which underlies the limestone there are fine springs.

In the lower exposure the sand beneath the drift is evidently older than the drift which it underlies unconformably. This sand in color and texture is like that which generally composes the Dakota sandstone, coarse and red. It is for the most part uniform in texture. In digging down five feet from the surface only one layer a few inches wide was found containing material coarser than sand. Interspersed were occasional layers of clay from one to three inches thick. The upper surface of the sand was cemented by iron into a solid sheet two inches thick. It seems that these sands were deposited by the river before the older drift of the region was laid down. The limestone that underlies the sand was doubtless the stream bed, while the shale, which a little farther back overlies the limestone, was the ancient bank. The Dakota sandstone was exposed to the north and contributed the material.

In the pit of the brick yard at the edge of the town of Hawarden, in Tp. 95 N., R. XLVIII W., Sec. 35, Ne. ¼, there is a good exposure of the upper shale. Its characteristics as here shown are the same as those already noted. The selenite is very abundant and is equally distributed throughout the exposure.

Going north along the river no other exposures are found till a point four miles south of Hudson is reached. Here, as in those exposures south of Hawarden, the river has recently been cutting into the east bank. This point is in Tp. 95 N., R. XLVIII W., Sec. 12, center. Eighty feet of the upper shale are disclosed, extending from the water's edge to the drift that caps the bank. Here, as elsewhere, selenite is abundant. Septarian nodules were found which have not been noted in the exposures farther south.

Six miles north of Hudson, at Fairview, on the Dakota side of the Big Sioux, Todd has found the following section:*

		FEET.
8.	Slope covered with bowlders and clay	50–100
7.	Drab pebbleless clay	14
6.	Unexposed	4
5.	Drab clay thinly laminated without fossils and pebbles	17
4.	Fine gray sand horizontally stratified	13
3.	Slope	40
2.	Lead-colored clay and shell fragments	5
1.	Shale with calcareous concretions, level of stream	2

On account of the layer of unconsolidated sand separating the upper clays in this exposure from the lower, which he regards as clearly Cretaceous, Todd is inclined to think that sections 5 and 7 in the series above belong either to the Pliocene or the very earliest Pleistocene. Allowing three feet per mile for the fall of the stream the water level here is twenty feet above that of the Hudson exposure, where eighty feet of undoubted Benton shale rise above the river. The surfaces of the two exposures, then, are about on the same level. The surface of the shale, however, before the drift was deposited would probably vary a few feet at the two points. The absence of selenite in five and seven of the Fairview series is perhaps the strongest reason for thinking that they do not belong to the Benton, and leads to the belief that they are to be classed with certain clays that are found farther north.

The next exposure to the north was found on the Chicago, Milwaukee & St. Paul railroad four miles east of Canton, in Tp. 98 N., R. XLVIII, Sec. 11, center. This point is three miles east of the river. It gave the following section:

		FEET.
4.	Drift, somewhat oxidized, with gravel	8
3.	Gravels, rusted, but slightly rotted	5
2.	Sand, very fine, unoxidized	20
1.	Clay, drab, without pebbles	6

The lower clay is homogeneous in texture and uniform in color except along joints where it is stained red. Care was

*Prelim. Rep. on Geol. S. Dak., 1894, Vol. I, p. 111.

taken to determine the presence or absence of pebbles. The surface was stripped to a depth of eight inches to remove material that had fallen from above. In excavating a cubic yard every spadeful of clay was minutely examined and not one pebble was found. The clay lacks the lamellar structure of the upper Benton. The sand is a striking feature of this exposure. It is extremely fine and resists erosion, presenting the vertical faces so characteristic of the loess. To the unaided eye it reveals minute mica scales, while the microscope shows that in the main it is composed of rounded quartz fragments.

In cuttings on either side sands in the same horizon are coarser and are everywhere water-bearing.

The clay probably corresponds to that of the upper members of the Fairview series. Everywhere in Iowa where the upper Benton is exposed it is so definitely characterized by the presence of selenite and its lamellar structure, that the absence of these characteristics here makes reasonable the supposition that the clays are younger than the Cretaceous.

The sand here exposed seems to be more than a local phenomenon. Well drillers report that in the vicinity of Inwood, which is two miles east of the exposure in question, they frequently encounter quicksand at a depth equivalent to that of these sands. At a corresponding level north of Sioux City Mr. Bain has found beds of fine sand overlaid with gray and yellowish clays with a few pebbles which do not seem to be of northern origin. In these sands were found teeth which Professor Cope identifies as *Equus major*. Cope assigned the sands to the Pleistocene.

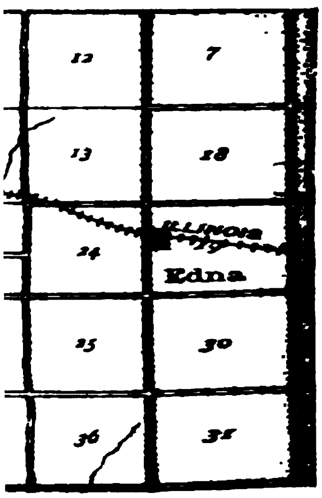
Very recently in the vicinity of Akron, Professor Todd has found elephant bones. These, however, were in the drift. It seems safe to infer that the sand and clay in these exposures is younger than the Cretaceous and older than the drift that is common in the vicinity.

THE PLEISTOCENE.

THE LOESS.

Excepting the areas indicated as having an abnormal topography, namely, the four townships forming a square in northeastern Lyon county and a narrow strip along the Big Sioux, north of Hudson, the entire surface of the region, save the lower valleys of streams, is covered with a deposit known as loess. In popular language it is called clay or loam, though it is generally understood that its description does not fully correspond with either. It is light in color, suggesting putty, fine grained, so that when dry and rubbed it blows like dust, porous as usually found, readily absorbing and holding water. When wet it is plastic, yet adhesive, and readily yields to the brickmaker's art. It resists erosion and when cut through, as in roadmaking, will present a face nearly vertical for years. It shows a tendency to crack along definite vertical planes, which at times gives rise to a structure roughly columnar.

It is free from pebbles and bowlders, and in this region they will be found on the surface only in lowlands or on hillsides where the loess has been washed away. The loess shades upward gradually into soil, which is simply the loess with matter of vegetable origin added. The result is a soil darker than loess, but lighter than that derived from drift or alluvium. The upper loess of Lyon and Sioux counties is generally leached, while the lower shows an abundance of lime. The lime often manifests itself in the form of concretions or lime-balls, which in size vary from that of a pea to lumps half an inch through. When broken open they resemble clay and are hollow, with cracks running from the center. They are formed by water, bearing mineral matter which it has obtained from the loess above. This material forms a coating about a nucleus, and as fresh matter is contributed the concretion grows. In regions where the surface loess is unleached there is often evidence to prove that erosion has removed the upper portion. The loess that abounds in these counties has another characteristic to which attention is called, inasmuch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as it helps to distinguish it from other material which may perhaps be called loess, but which differs from the typical loess of the region. This characteristic is its mottled appearance, which appears only on close examination. The colors present are red and buff, as though in spots more iron were present or oxidation had gone farther. Very often, though not always, there are black spots which seem to be of vegetable origin. At times the loess shows slight lamination, the planes being horizontal. No fossils have been found in the loess of this region, though they are frequently associated with it elsewhere. In thickness it is variable. On the bluffs three miles south of Hawarden it is twenty feet thick. An average thickness is six feet. On the hillsides it is often slightly thicker than on the crestis. The line between the loess and underlying drift is invariably well defined. The drift and

FIG. 7. Section in Tp. 100 W., R. XLIV W., Sec. 18, one mile south of state line, showing sharp line between loess and drift.

stratified material that underlies it always give the contour of the region, and the loess is simply a veneer, never seriously affecting the topography.

THE DRIFT UNDERLYING THE LOESS.

In Lyon and Sioux counties drift is everywhere found underlying the loess. Well drillings already quoted show that its

thickness is about 200 feet. In the loess covered region the characteristics of the drift are quite uniform, though this drift varies decidedly from that of northeast Lyon county where loess is absent. The best opportunity for studying the drift is found in the railroad cuttings which are abundant in both counties. A typical cutting is given in the accompanying sketch. It is found in Tp. 95 N., R. XLV W., Sec. 20, Se. ¼, on the Sioux City & Northern railroad, two miles south of

FIG. 8. Typical section through drift and loess in Lyon and Sioux counties, showing position of intervening gravel and sand layer.

Sioux Center. About fifteen feet of drift are found under seven feet of loess. The line between the two is distinct. Directly under the loess here, as in very many other places, there is a layer of gravel varying in thickness from a few inches to two feet. In place of gravel, sand is sometimes found. Where both sand and gravel are lacking there is invariably a line of rock fragments varying in size from pebbles to bowlders two feet through. It may be said without exception that on the surface of the drift, fragments of rock coarse or fine have accumulated in quantities greater than in an equal area of the drift below. In two cases wind-polished

bowlders were found resting on the surface of the till and projecting upward into the loess. These were found in cuttings in Tp. 98 N., R. XLVII, Sec. 28, Sw. ¼ and Tp. 100 N., R. XLIV, Sec. 18 Ne. ¼.

In other localities similar bowlders were found in like positions, but their surface characteristics were not definite enough to render at all certain the statement that they show the effects of wind action. The subsequent decay of the surface of many bowlders has obliterated characteristics that were once clear. In the first case cited a granite bowlder eighteen inches in diameter is buried but slightly in the drift and projects into the loess more than a foot. The upper side is beautifully polished and calls to mind at once the wind polishing on the quartzite already referred to. Its surface is covered with indentations

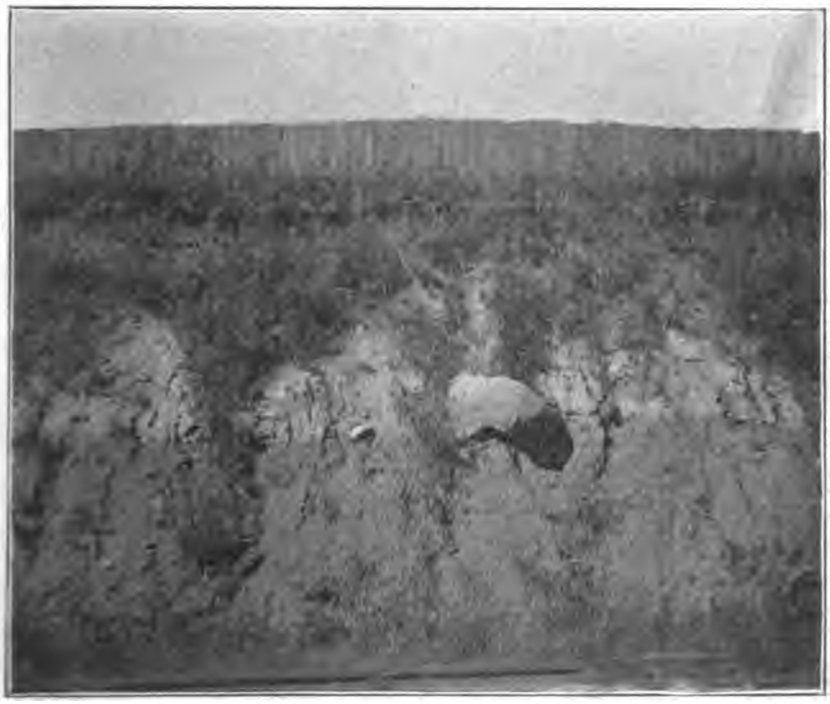


FIG. 9. Wind polished bowlder resting on drift and projecting into loess. The figure shows nicely the sharp line between drift and loess.

and irregularities and there is no suggestion of planing and yet, regardless of the unevenness, it is uniformly polished. It is strikingly different from bowlders planed, striated and polished by ice. The wind with material that it carries are the only agents to which polishing of this sort can be attributed. The fact that the under surface which rests on the drift is unpolished bears out this belief.

The amount of rotten material that rests on the surface of the drift is more abundant proportionately than that scattered through it. In the drift bowlders, granite predominates when the entire area is considered, but in the western half of both counties quartzite is most abundant. In the pebbles there is a greater percentage of limestone, perhaps one-fourth of all the smaller rock fragments being of this material. Next in order of abundance are granites, greenstone and quartzite. The pebbles and sand on the surface of the drift are usually badly rusted and stained.

The upper part of the drift is invariably darker than the lower, the color shading off gradually through six or seven feet. This darker color is due to the oxidizing of the iron in the clay. This dark rusty red follows the joints into the lighter clay below, extending back from the joints about an inch on each side. Away from the joints the lower drift is but slightly oxidized. The upper drift is not dark enough to be called ferretto, and apparently oxidation has not gone as far as in the southern part of the state where the very dark surface band is developed to which this term is applied. The drift is nearly everywhere unleached and responds vigorously to the acid test. Lime concretions like those found in the loess are common near the surface.

In the following railroad cuttings loess and drift like that described are exposed:

On the Illinois Central:

Tp. 99 N., R. XLV W., Sec. 10, Se. ¼.
Tp. 99 N., R. XLV W., Sec. 14, Se. ¼.
Tp. 97 N., R. XLIII W., Sec. 10, Sw. ¼.
Tp. 97 N., R. XLIII W., Sec. 36, Ne. ¼.

On the Chicago, Milwaukee & St. Paul:

Tp. 97 N., R. XLIII W., Sec. 36, Nw. ¼.
Tp. 97 N., R. XLV W., Sec. 29, center.
Tp. 97 N., R. XLVI W., Sec. 25, center.
Tp. 97 N., R. XLVI W., Sec. 26, N. ½.
Tp. 98 N., R. XLVII W., Sec. 28, Sw. ¼.
Tp. 98 N., R. XLVIII W., Sec. 11, Se. ¼.

On the Burlington, Cedar Rapids & Northern:

Tp. 100 N., R. XLIX W., Sec. 26, Ne. ¼.
Tp. 100 N., R. XLIV W., Sec. 18, Ne. ¼.

On Sioux City & Northern:

Tp. 95 N., R. XLV W., Sec. 5, Sw. ¼.
Tp. 97 N., R. XLV W., Secs. 8 and 6, a series of cuttings.

On Chicago & North-Western:

Tp. 94 N., R. XLV W., Sec. 17, Ne. ¼.
Tp. 94 N., R. XLV W., Sec. 18, Ne, ¼.
Tp. 94 N., R. XLVIII W., Sec. 1, center.

Well drillers report that large bodies of sand are met with in the drift, and all of the wells in the region more than thirty feet deep and less than a hundred, end in these sand layers. In thickness they vary from six to thirty feet. In some places they are dry, but often they yield a considerable supply of water, showing that they underlie more than a limited area. On the Milwaukee road near the town of Perkins such a layer of sand ten feet thick is exposed. The locality is Tp. 97 N., R. XLVI, Sec. 25, center. Well drillers also state that the yellow bowlder clay persists to a depth of eighty or one hundred feet, and is succeeded by blue clay, which continues until the shale is reached. The alternation of blue and yellow clay is also reported, but so vaguely that it seems impossible to determine what it may signify.

Age of the Drift under the Loess.—With hardly an exception the geologists who have studied the drift of Iowa believe that the state has been invaded by more than one ice sheet, and that there were considerable lapses of time between these invasions. One reason for so thinking is the frequent discovery of buried forests and peat beds in the midst of drift. Such

discoveries are reported from all parts of the state, one particularly interesting example occurring in Lyon county. In most of these instances logs and peat are encountered in well digging. These discoveries are altogether too numerous and too well authenticated to be disputed, and prove that the ice sheet that deposited the lower drift must have retreated at least for an interval sufficient to permit vegetation to gain a foothold. In the second place buried soils, that is, drift mixed with humus, are frequently encountered. The soil that has formed on the surface of the latest drift is but twelve to fourteen inches thick. Soil lines much thicker buried under many feet of drift are frequently encountered, and the inference is that a longer interval elapsed before the upper drift was deposited over this now buried soil than has passed since the last drift sheet itself was deposited. Thirdly, where old soils are so buried the clay beneath is generally leached. The water percolating through the soil near the surface takes its lime in solution and deposits it elsewhere. Water has little access to deeply buried drift except along sand and gravel horizons through which water is flowing. Leaching, therefore, generally accompanies other signs of old surface lines. The extent of leaching depends not only upon the length of time that the drift was on the surface, but also upon the amount of water percolating through it. Under certain conditions, therefore, it would be possible to have an unleached soil, though it had long been exposed at the surface. A fourth proof that former drift surfaces have been covered by subsequent drift is found in buried zones of oxidized material. Exposed to the air the iron, always abundant in clay, is changed from the blue ferrous oxide to the red ferric, the depth of coloring varying with the degree of exposure. This in turn varies with the nature of exposure and length of time that the drift was subject to atmospheric action. The lower the drift below the soil line the lighter the color, till it passes from the red through yellow to simple blue clay. Again, in connection with other phenomena indicating an old surface

line buried by subsequent drift, are proofs that erosion to a greater or less extent has modified the former surface. Such proofs are found in accumulations of pebbles and bowlders, evidently once mixed with the clay, as in drift, but left behind while the lighter material was washed away. It is possible, of course, that such deposits were due to water action contemporaneous with the ice sheet, yet when they occur prevailingly over large areas the former explanation often seems more reasonable.

The occurrence of any one of these phenomena in a given region would hardly prove conclusively that there were at that point two or more drift deposits. When, however, many or all of the phenomena cited occur together as they do throughout the state, the proof seems adequate.* Working along these lines the geologists of the United States Survey and of the states of Iowa and Illinois have determined the following drift sheets.

The Wisconsin, the youngest, overlies the others when they occur in the same vicinity. Its topographic features, likewise, show that its age is not great. In Iowa it extends in a narrow lobe from the northern boundary of the state as far south as Des Moines. Its western border, as will be shown later in this report, barely enters northeastern Lyon county. In northeastern Iowa there is a drift sheet older than the Wisconsin, and in places lying under it, to which the term Iowan has been applied. Earlier than the Iowan ice was the Illinoian which moved from the northeast and entered Iowa for only a few miles beyond its eastern boundary. More general than these and earlier was the Kansan ice invasion, which covered the entire state and extended on to the south. Below the drift that is plainly Kansan, and separated from it by gravel beds, in certain localities is found a drift that is believed to be pre-Kansan.

The drift of northwestern Iowa has never been positively identified with any of these drift sheets, though it has been

*See proceedings Iowa Acad. Science, Vol. V, pp. 64—100.

thought that more careful study would result in associating it with some one of them. One of the reasons for undertaking at this time the geological study of Lyon and Sioux counties was to obtain, if possible, more light on this problem. The same drift is found to the south under the loess in Plymouth and Woodbury counties, while still farther south, in Carroll county, the drift was recognized as Kansan. No break or line separating this Kansan drift from that of the northwest having been found, unless there were other proofs to the contrary it would be natural to regard the drift of the northwest as Kansan. The study of Plymouth, Woodbury, Lyon and Sioux counties has brought out certain difficulties in so associating it. First, in the Kansan of southern Iowa, oxidation has gone farther than in the drift of Lyon and Sioux counties. In Appanoose county, for instance, and in Polk county under the Wisconsin, the Kansan drift has been so thoroughly oxidized that it presents a very dark band four feet thick. To this band the term ferretto has been applied. The oxidized zone in the drift of the northwest is not as well developed though it is sufficient to make a strong contrast with the unoxidized Wisconsin. Secondly, the drift of Lyon and Sioux counties is practically unleached while the known Kansan farther south is almost free from lime for three or four feet below the surface.

Opposed to these objections are the following considerations: First, as already stated, no line of demarkation has as yet been found separating the drift recognized as Kansan from that of northwestern Iowa. In parts of Carroll county drift recognized as Kansan lacks the ferretto zone* and this has been accounted for by supposing that erosion has been unusually rapid at those points. Toward the north the oxidation seems to diminish. There is an interesting cutting on the Illinois Central railroad half a mile east of Sioux Falls, S. Dak., which presents the following section:

*Iowa Geol. Survey, Vol. IX, p. 87.

		FEET.
5.	Sandy loess, in places sand	1- 3
4.	Drift, unoxidized, with fresh pebbles...............	6-10
3.	Silt, slate color with shells.........................	3
2.	Gravel, stained, partially decayed.................	1- 2
1.	Drift with ferretto very distinct...................	15

The oxidation of the lower drift at this point is as great as in the typical Kansan. The gravel above it is like that above the drift in parts of Lyon and Sioux counties. On the north side of the cutting it is nearly two feet thick, while on the south side only six inches. It is replaced on the south side by silt containing many fresh water shells and bones of turtles. The shells have been identified by Professor Shimek as follows:

1. *Planorbis bicarinatus* Say.
2. *Planorbis parvus* Say.
3. *Physa heterostropha* Say.
4. *Limnea caperata* Say.
5. *Valvata tricarinata* Say.
6. *Sphaerium sulcatum* Prime.
7. *Pisidium compressum* Prime.
8. *Vallonia costata* Ster.

"Of these, one to four are Pulmonates, five is a gill bearer (Prosobranch), six and seven are bivalves, and eight is terrestrial. The set one to seven can be duplicated in most of our northwestern ponds with muddy bottoms. Eight is terrestrial, but grows sometimes near the edges of ponds and is common along streams. There is one specimen of this."*

The overlying drift is light colored, unleached and carries fresh rock fragments. It, in general, resembles the Wisconsin of other localities.

Similar exposures are found in the northern part of the town of Sioux Falls, at several points near the brewery on Main street. The beds are on about the same level as those east of town. The drift below the silt at these points shows no ferretto, and oxidation has gone about as far as in the drift of Lyon and Sioux counties. The extreme oxidation seen east of Sioux Falls seems to be quite local.

*Proceedings Iowa Acad. Sciences, Vol. VI, p. 125.

In other respects the exposures are practically the same. These points were visited by Salisbury, Bain, Leverett and Todd, and the lower drift pronounced Kansan. The question remained whether the upper or lower drift was to be correlated with that of northwest Iowa. The resemblance of the overlying drift to the Wisconsin has impressed all those who

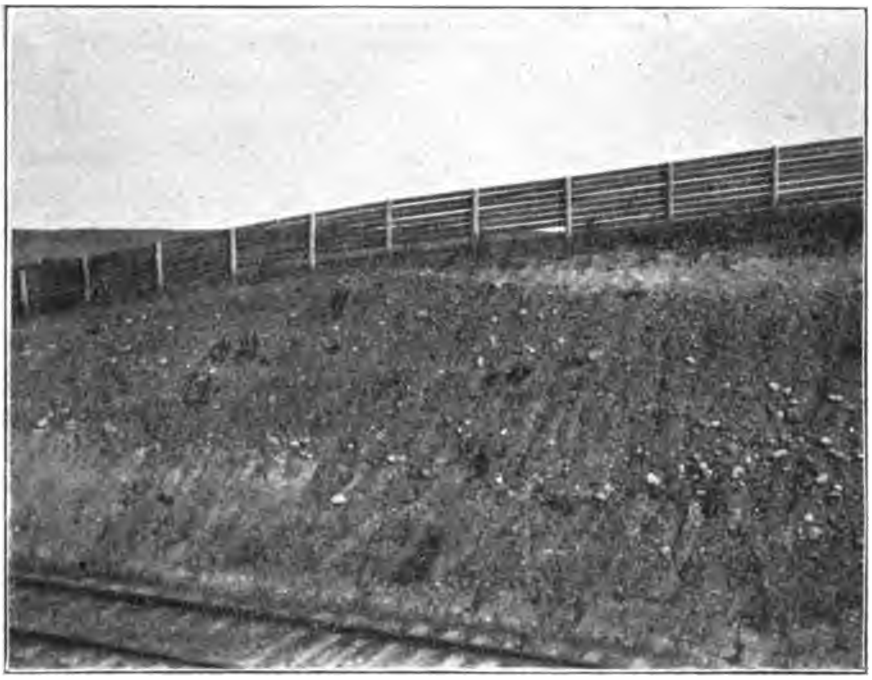


FIG 10. Exposure east of Sioux Falls, S. Dak., showing Kansan drift under Buchanan gravels, and these in turn under Wisconsin drift. (After Todd.)

have seen these exposures. Conspicuous kames of Wisconsin material in the vicinity, two miles south of the falls on the south side of the river, have been noted by a number of observers. The study of the Wisconsin moraine in connection with this report has made plain that the exposure on the Illinois Central east of Sioux Falls is on the edge of the moraine, and that the loam and sand associated with it are to be referred to the Wisconsin. Similar deposits of sandy loess were found associated with the Wisconsin moraine in other

localities. There seems to be very good reason, therefore, for associating the lower drift at Sioux Falls, which is regarded as Kansan, with the drift of northwestern Iowa, for the older drift in northwestern Iowa in all probability corresponds to one of the two drifts in the Sioux Falls exposure. It is of course possible that the Lyon county drift is not to be associated with either of the drifts at Sioux Falls, but the distance between the localities is so short that the Lyon county drift can hardly be considered a third deposit. The drift in northwestern Iowa is plainly not Wisconsin, therefore if it coincides with either of the drift sheets exposed at Sioux Falls it must be with the lower or Kansan.

Topographically the Kansan drift of southern Iowa has been regarded as older than that of Lyon and Sioux counties. The high gradients of the streams already cited is indicative of youth. Yet streams of similar size flowing over undoubted Kansan drift have as great a fall. English river in Washington county descends 3.3 feet per mile, while Skunk river, in the same county, falls 2.75 feet in each mile. Iowa river, at Iowa City, Johnson county, has a slope of 3.5 per mile, while its tributary, Old Man creek, has a gradient of 5 feet per mile.

In many places the gravel that so generally lies on the drift just beneath the loess in Lyon and Sioux counties suggests a similar zone found elsewhere above the Kansan. These gravels are so prevalent above the Kansan that they have been given a distinct name from the locality where they were first carefully studied, Buchanan county. Professor Calvin, in describing the Buchanan gravels, calls attention to the following characteristics. The material has been derived chiefly from northern sources, though fragments of fossiliferous limestone that have not been transported for any considerable distance are not rare. Similar rock fragments are commonly disseminated through the Kansan. A large proportion is dark-colored greenstone, with a high percentage of the individual

fragments planed and scored. Certain granites and representatives of other rock species are completely decayed, so that blocks a foot in diameter fall to pieces under a single blow of the hammer. The gravel is exceedingly ferruginous in places and is everywhere much stained and weathered, particularly near the top of the deposit, the weathered portion taking on a characteristic reddish-brown color. These characteristics are often found in the gravels overlying the drift of Lyon and Sioux counties. In these counties there is a high percentage of quartzite present, which would be expected when the nearness of the quartzite exposures is taken into account.

On the west bank of the Big Sioux near Canton and on the east bank near Klondike there are exposures of gravel which, except for the added element of quartzite, correspond in composition and structure in every way to the description quoted above. A finely developed Wisconsin gravel train follows the Big Sioux, whose fresh gravels are in marked contrast to the rusted and decayed material in the two localities mentioned. On account of these contrasts it is impossible to associate the gravels at these points with the Wisconsin train, though their position would not necessarily exclude them. They are probably relics of a former train dating back to the time when the Buchanan gravels elsewhere were being deposited along the edge of the retreating Kansan ice. Their position favors this belief, though not compelling it, for they lie slightly above the level of the Wisconsin gravels, relics of a former terrace. On the Illinois Central in Tp. 99 N., R. XLV, Sec. 10, Se. ¼, near Edna, similar gravels are exposed. While there is a gravel horizon almost invariably above the drift the age of the material at many points does not seem as great as at the points noted. This raises the question whether the gravels are not of different age and origin, the older beds being Buchanan gravels and the younger a residual deposit belonging to the interval following the Kansan ice, called by Leverett the Yarmouth. The Buchanan gravels as intrepreted by Calvin are a definite outwash of the Kansan ice, and as the

ice retreated gradually the deposits of glacial floods would be found not along the limits of the Kansan drift but on its surface. The cross-bedding of the Buchanan gravels suggest such an origin. If the Kansan drift was long exposed as surface soil, gradual erosion of the lighter material would leave on its surface the gravel and bowlders that were once mingled with the clay. Such gravels would represent the Yarmouth interval. Most of the gravels on the drift of Lyon and Sioux seem to belong to this latter class.

The study of Lyon and Sioux counties, then, furnishes the following suggestive points with reference to the age of the drift in the northwestern part of the state. (1). The slope of the streams is no greater than that of like streams on undisputed Kansan. (2). Oxidation in places has been carried as far as in Kansan. (3). Gravels are present at various points above the drift like the Buchanan gravels above the Kansan. On the other hand, most of the drift, while oxidized to a certain degree, seems fresher than the Kansan where it is typically developed. Secondly, the drift is generally unleached, while the lime has been removed from the upper part of the Kansan. From this it does not necessarily follow that the drift is young. The amount of leaching is determined in part by the quantity of water that circulates through the lime-bearing stratum, and if the surface of a given region is relatively low so that there is little or no tendency for water to penetrate the soil, long lapses of time may result in very little leaching. On the other hand, if the gradients were high, surface drainage would be increased and little water would penetrate the drift. This also would account for absence of leaching. Leaching goes on most rapidly where slopes are moderate. High gradients also result in rapid erosion, and for this reason Mr. Bain, in Carroll county, accounts for the absence of ferretto and leaching in certain parts of the Kansan drift. The amount of rainfall* in the northwestern part of the state is less than that farther south, amounting to

*Iowa Geol. Survey, Vol. IX, p. 67.

twenty-two inches, as compared with twenty-five to thirty-two in the southeast†. The rainfall is confined more to certain seasons and is more abundant in limited periods. This also would help to explain the unleached drift.

It is possible to correlate the drift with the Iowan of the eastern part of the state, which it resembles somewhat in its limited oxidation and leaching. The loess has often been regarded as related with the Iowan drift, something after the manner of an outwash. If this is true the drift beneath it could not be Iowan, for the underlying drift shows that a considerable interval elapsed before the loess was deposited. In a later paragraph on the origin of the loess, reasons for questioning whether the loess is a water deposit are advanced. It is, therefore, doubtful, whether any argument in regard to the age of the loess-covered drift, can be made from stratigraphic relationship.

Topographically the drift is, perhaps, more closely related to the Iowan. The valleys are not as extensive as those on the Kansan drift in the southern part of the state. It is clearly distinguished from the typical Wisconsin, however, by the completeness of its drainage. The average rainfall of Lyon county is eight inches less than that of southern Iowa. This fact permits the drift of Lyon county to be Kansan, even though its topographic features are not so fully developed as might be expected from study of the same drift in other regions.

Considering everything, it seems safer to consider the loess-covered drift of Lyon and Sioux counties as Kansan until something is found in the way of a southern boundary to distinguish it from the recognized Kansan farther south.

THE ALTAMONT MORAINE.

The topographic features of northeast Lyon county have already been described, and from the ridges and hummocks that characterize the region it will readily be put down as morainic. This inference from topography is borne out by

†Report Iowa Weather and Crop Service, 1894, p. 52.

the nature of the hummocks, since they are for the most part composed of gravel. The accompanying sketch from photograph, taken in Tp. 100 N., R. XLIII W., Sec. 23, Se. ¼, just north of the town of Little Rock, shows a morainic knob on the very top of which is a gravel pit. The limits of the moraine are best shown by the accompanying map of the Pleistocene. There is no loess covering the morainic area

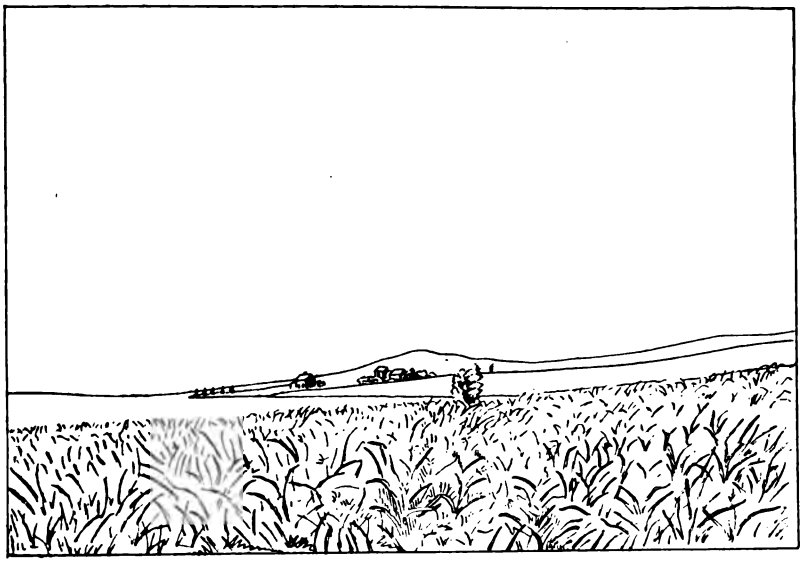


FIG. 11. Morainic knob near Little Rock, Lyon county.

and surface bowlders are common. The material of the moraine is fresher than that which underlies the loess. Its color is yellow and it is but slightly oxidized. It often contains rock fragments, but they are as abundant in the lower part of the drift as near the surface. It is invariably unleached. The outer ridge of the moraine, from Lyon county, trends to the northwest, and on it is located the town of Adrian, Minn. In Lyon county all of the region not loess-covered is morainic, and to determine what lies within the moraine it is necessary to go north into Minnesota. Going east from Adrian the moraine is found to be three miles wide. It gives place to level country with gradually increasing

elevation till the surface is raised 100 feet above Adrian. On this elevated ground the town of Rushmore is located. Three miles east of Rushmore is the moraine of the Coteau des Prairies. The characteristics of this moraine are in the main those of the outer moraine already described. In each case the hummocks that so definitely mark a region as morainic are abundant in certain localities and almost wholly absent in others. When Upham described Murray and Nobles counties in Minnesota, which lie directly north of Lyon county and into which the Altamont moraine—as the outer moraine of the Wisconsin is called—and the Coteau des Prairies extend, the Altamont moraine was not recognized, though attention was called to the rolling till outside of the moraine of the Coteau. His description in this connection is interesting.* "Here and northerly into Murray county this most prominently rolling and highest part of the Coteau des Prairies in this latitude forms the watershed between the basins of the Mississippi and Missouri rivers. Its connection with the roughly hilly and knolly outer terminal moraine traced from central Iowa northward to Spirit Lake and thence westerly to Ocheyedan mound south of this county, and still more prominently exhibited along the crest of the Coteau des Prairies in western Nobles county, and thence northwesterly to the head of the Coteau, shows that the border of the ice in the last glacial epoch extended to this belt of massively rolling till; but though it thus represents the outer moraine of that epoch, it nowhere in Nobles county has such roughly broken knolls and small, short, steep ridges as are common along nearly all of the rest of this morainic line. *Farther westward the surface of Nobles county is in swells of till which trends mostly from north to south, more massive and smoother than those which form the outer terminal moraine and of about the same elevation; or in nearly level equally high plateaus of till, as at Rushmore, ten miles west of Worthington.*" The italics are ours. The till outside of the Coteau des Prairies in Lyon county is more typically morainic

*Geol. and Nat. Hist. Survey, Minn., Vol. I, p. 520.

than that described by Upham in Nobles county. But, taking his description for the region outside the Coteau, with the added light given by study of the relative oxidation of the drifts of the region, and our present understanding of the loess, we would be justified in expecting a moraine on the outer edge of the non-loess-covered drift west of the Coteau.

Outside of the Altamont moraine in Lyon county and following its course is the level belt spoken of in connection with the topography of this part of the county. This belt averages four miles in width. It persists as a border for the moraine into Minnesota and into Osceola county, Iowa. In Nobles county, Minn., Upham thus describes it.* "The only noteworthy deposit of this kind (modified drift) is that found in Grand Prairie, the most southwest township in Nobles county. Here a plain composed of stratified gravel and sand, but covered with a fertile soil, reaches six miles east from Kanaranzi creek, with a width of about four miles, including the southern two-thirds of this township." The thickness of this gravel as shown by well borings at Ellsworth, Minn., is six feet. In Lyon county exposures of this water-laid gravel may be found in Tp. 100 N., R. XLIV, Sec. 36, Se. ¼, in a sand pit near the roadside; in Tp. 100 N., R. XLIV, Sec. 14, Sw. ¼ on the banks of Tom creek, and cellars at the following points:

Tp. 99 N., R. XLIV W., Sec. 1, Ne. ¼.
Tp. 100 N., R. XLIV W., Sec. 25, Sw. ¼.
Tp. 99 N., R. XLIII W., Sec. 4, Se. ¼.

In Iowa as noted by Upham for Minnesota, the sand and gravel of this strip are covered with a fertile soil. This soil is akin to loess but more sandy. It does not have the mottled appearance noted in the loess that is common to Lyon and Sioux counties, and Upham for Nobles county, Minn., excludes the region from the loess-covered area.† The nature of this soil is variable, at times closely resembling loess in texture, while in the immediate neighborhood it appears as moderately coarse sand. In two instances this sandy loam appears at

*Geol. and Nat. Hist. Survey, Minn., Vol. I, p. 527.
†Geol. and Nat. Hist. Survey, Minn., Vol. I, p. 526.

some distance from the moraine on the banks of streams over gravel which appears to be of Wisconsin age. The first is in southeast Lyon county on the banks of Otter creek in Tp. 98 N., R. XLIII W., Sec. 32, Se. ¼; the second is on the banks of the East Floyd just west of Hosper in Tp. 95 N., R. XLIII W., Sec. 10, Nw. ¼. The more conspicuous gravel trains of the Wisconsin are covered with alluvium which does not so closely resemble loess. In a railroad cutting on the Burlington, Cedar Rapids & Northern, in Tp. 100 N., R. XLV W., Sec. 23, Se. ¼, typical loess mottled, having the black specks spoken of, is found under three feet of this sand and loam. This cutting is shown in the photograph.

FIG. 12. Sandy loess and sand, overlying typical loess in Lyon county.

The difference in color between the two deposits is in part due to the fact that the loess below holds the moisture longer than the more sandy material above. Similar conditions are shown in a road cutting three miles northwest of Rock Rapids in Tp. 100 N., R. XLV W., Sec. 22, Sw. ¼. Here, how-

ever, the loess-like material above the true loess contains coarser matter, not infrequently rock fragments a fifth of an inch in diameter being found. This cutting is on the banks of Kanaranzi creek.

The evidence seems sufficient to prove that the gravel area is a real outwash from the Wisconsin, and it is probable that the loess-loam above it had a similar origin. It is much easier to think of this deposit which covers a limited area and is directly associated with other water deposits as a phase of the outwash, than it is to conceive of the normal loess as due to the agency of water.

Altamont Moraine in Western Lyon County.—Lyon and Sioux counties lie between two lobes of the Wisconsin drift. A portion of the eastern lobe is found in northeast Lyon county. The western lobe is found in Dakota, its western boundary consisting of a moraine which follows the Missouri river as far south as Vermillion. It then bends north and east to Canton. In this connection Todd writes: "There comes a gap between Vermillion river and Brule creek, probably caused by a narrow ice lobe. The moraine extends along Brule creek northward to Beresford and on to a high point south of Canton. It is then feebly developed or entirely absent from that point to the west side of the Big Sioux opposite the northwest corner of Iowa. There it forms a ridge running westward to the East Vermillion river."* The study of Lyon and Sioux counties leads to a partial restatement of the nature of the moraine along the Big Sioux. Instead of being absent from Canton to the northwest corner of Iowa, data will be brought forward to show that at one point at least it is found just east of the Big Sioux river, and that instead of running west from northwest Iowa as a ridge to the East Vermillion river it extends northwest to Sioux Falls, then across the river just northeast of that town, and continues almost due north on the east side of the river. If these points are satisfactorily demonstrated it will be impossible to account for the great

*Prelim. Report on Geol., S. Dak., 1894, p. 115.

bend in the Big Sioux at Sioux Falls as deflection caused by the moraine, and a cause antedating the moraine must be ascribed.

The most conspicuous topographic feature along the Big Sioux is the difference in elevation between its east and west banks. From Canton to Granite the bluffs on the Iowa side are 150 feet above those on the Dakota side. The drift on the Dakota side has the characteristics of the Wisconsin and has been so regarded. The drift on the east side is that which in this report is regarded as Kansan. The only available explanation for this difference in elevation is found in supposing that at this point the Wisconsin ice removed more material than it deposited as ground moraine. The older drift so removed, however, must have been deposited at the edge of the ice as terminal moraine or carried away by stream action as fast as brought by the ice. Precisely at the points where a very strong moraine would be expected it is weak or lacking altogether. Well drillings at Hudson, in the valley of the Big Sioux, show that the valley of the stream at that point is cut deep in the Benton shale and is partly filled with drift. The valley of the Missouri at Sioux City is filled with drift to a very great depth. A gravel train of unusual size attends the Big Sioux from northwest Iowa to Sioux City. These facts lead to the belief that the material that would otherwise remain as a moraine at the eastern edge of the Dakota lobe has been removed by the river that ran along its edge, and deposited in these valleys. Certain facts lead to the belief that remnants of the moraine are still to be found on the Iowa side for ten miles south of the state line, and then on the Dakota side.

In the northwestern corner of Lyon county, west of the town of Granite, in Tp. 100 N., R. XLIX W., Secs. 25 and 26, the Big Sioux flows through a narrow gorge in no way commensurate with the valley above or below. Looking down the river from the vicinity of Rowena, S. Dak., one would hardly suspect that the river flowed through the narrow pass to the

right, but would think that it turned to the left and followed the broader valley of Blood Run creek. Reference to the accompanying topographic map gives the same impression. On the west side of this gorge is a knob that is a conspicuous feature of the landscape and shows plainly on the topographic map. This is the end of the morainic ridge recognized by the South Dakota Survey. On the east side of the river at this point there is a most interesting cutting on the Burlington, Cedar Rapids and Northern railroad. It is shown in part in the accompanying photograph. Beneath a younger drift is

FIG. 18. Railroad cutting west of Granite, showing Wisconsin moraine over older drift.

the older characteristic drift of Lyon county. The surface of the older drift is uneven, having evidently been exposed to erosion for a long time before the younger drift was deposited. The upper drift completely fills the hollows in the older and caps the crests. The line between the two is very sharp.

The upper drift abounds in huge bowlders, many of them of fossiliferous limestone. A brachiopod, *Orthis testudinaria* is abundant in these limestone blocks. The surface at this point is dotted with gravel knolls, from five to ten feet high and varying in diameter from twenty to fifty feet. They are irregularly distributed and are hard to account for unless a morainic origin is ascribed to them. Traces of flint implements and shells are not sufficiently abundant even to suggest for the mounds an artificial origin, and the hummocks are too numerous and too limited to this area to be regarded as freaks of erosion. Evidently the ice crossed the river at this point and this is a part of the moraine. Following the east bank of the river still farther south other proofs that the ice reached the Iowa side appear. The drift is fresher looking than that outside the Wisconsin. This is true, however, only for a strip not more than two miles wide along the river. The moraine that crosses the river at Granite as a distinct ridge does not long so continue, and if farther south it ever was in the form of a ridge, its definite form has been broken down by erosion. Two miles south of Granite and a mile east of the river, by the roadside, the older drift is exposed under loess and above the loess is a thin layer of drift. For a considerable distance, on a line a mile east and parallel with the river, bowlders are common on the surface of the loess. These bowlders and the drift spoken of as at one place overlying the loess may represent remnants of the moraine. It is possible, though hardly probable, that they are but a part of the older drift washed down on the loess from greater elevations.

The valley of the Big Sioux from Granite to Canton is narrow as compared with the valley above at East Sioux Falls or below at Hawarden, at which points it does not appear to have been interfered with by the Wisconsin ice. The only explanation that offers itself is that it was in part filled by morainic material.

Three miles northeast of Canton distinct morainic signs are found west of the river. Here a knob 140 feet high and a mile

long is conspicuous from every point for miles around. At the northeast corner of the town of Canton there is a similar gravel mound sixty feet high, on which the water tower stands. Both of these mounds are brought out plainly on the topographic map.

From the point where the moraine crosses the river, west of Granite, to Sioux Falls it is easily traced as a well defined, bowlder-strewn ridge. It passes east of Sioux Falls and crosses the river two miles northeast of the town. At the point of crossing several well-defined kames were developed. Thence for ten miles it was traced nearly due north.

While the ice blocked the valley of the Big Sioux west of Granite the water normally drawn off by this stream must have been thrown over into tributaries of Rock river, and particularly into Mud creek. The natural outlet toward the east was the valley of Blood Run creek and this fact would account for the great quantities of gravel, sufficient almost to be considered a gravel train, along the banks of this creek. Typical exposures of these gravels are found in Tp. 100 N., R. XLVIII W., Sec. 16, center, in cuttings on the Burlington, Cedar Rapids & Northern railroad. In any other way it is difficult to account for these gravels, for they are too abundant to be regarded as residuum from the wash of the slope, and the sources of the streams are not near the moraine. Topographic maps of northwest Lyon county, and Rock county, Minn., in which both Blood Run and Mud creeks have their sources, show that such a diversion of the waters of the Big Sioux would follow if the glacial dam increased the height of the water 100 feet. Back of the dam there must have been a temporary lake. Perhaps this lake was responsible for the silt found in the vicinity of Sioux Falls. A subsequent slightly greater advance of the ice would cover it with the Wisconsin drift, leaving it as now found.

Wisconsin Gravel Terraces.—Attention has been called to the unusual quantity of gravel present as outwash along the Altamont moraine in northeastern Lyon county. Where streams

already existed the water that issued from the ice flooded the banks and the current was strong enough to carry rounded rock fragments, two inches in diameter and under, long distances. The rivers so flooded were the Big Sioux, and Rock river with its tributaries in Lyon county. Throughout its entire course between South Dakota and Iowa the Big Sioux ran along the edge of the moraine and while the Wisconsin ice lasted must have discharged vast quantities of water into the Missouri. If the two lobes of the ice were synchronous it is possible that the interlobate position of this region accounts for the abundance of the outwash gravels. The gravel train in the older portion of the Big Sioux valley is a mile and a half wide. The present flood plain lies below the gravel terrace about ten feet and is relatively insignificant, averaging perhaps a fifth a mile in width. At Fairview, eight miles south of Canton, the Chicago, Milwakee & St. Paul railroad has taken a great deal of gravel from this terrace for ballast. In this pit bowlders are present in great numbers. In other localities where the Wisconsin gravel terraces have been exposed by cuttings, the material of which they are composed is shown to be very uniform in size and bowlders are rare. Bowlders in this pit are often two feet in diameter and may have come from the Wisconsin moraine, which is eight miles away. Taken in connection with facts which will be considered in a paragraph on the pre-Wisconsin course of the Big Sioux, it seems more probable that they were washed out of the Kansan drift, through which the stream was cutting when the gravel terrace was formed. In Tp. 100 N., R. XLIX W., Sec. 25, Nw. ¼, a mile west of Granite, the Burlington, Cedar Rapids & Northern has a gravel pit from which a limited amount of material has been taken. The Rock river touches the Wisconsin moraine in Minnesota, and its branches, the East Rock and Tom creek, drain portions of the outwash region in eastern Lyon county and western Osceola. The gravel terraces on the Rock river and its main tributary, the East Rock, are half a mile wide in Lyon county, while in Sioux

county the terrace of the Rock river is even wider, the two streams having united above. Extensive gravel pits in the Rock river terrace have been developed by the Chicago, Milwaukee & St. Paul, on the west bank of the river at Rock Valley, and by the Sioux City & Northern at Doon. The gravel is finer than in the Big Sioux terrace, and more evenly sorted. Abundant examples of oblique lamination occur in these pits.

Pre-Wisconsin Course of the Big Sioux.—In a single glance at the course of the Big Sioux as shown on the map the attention is caught by the peculiar bend near Sioux Falls. After flowing south to this point, the river turns abruptly to the northeast, holds this course for eight miles, and then as suddenly resumes its course to the south. The morainic ridge east of Sioux Falls at once suggests that the stream was deflected by the Wisconsin ice and the material that accumulated along its face. The map shows that at the point where the river again turns to the south it is joined by Split Rock creek, a stream of some importance. The first inference would be that the Big Sioux, when diverted from its normal course by the ice, was thrown over into the valley of Split Rock. This attractive hypothesis, however, is not sustained by a more careful study of the region. In the first place, the Big Sioux was not deflected by the moraine, but cuts through it, east of Sioux Falls. North of this point it flows along the inner edge of the moraine, while to the south it follows the outer edge for some distance, with the exception noted near Granite. The valley of the Big Sioux at the "big bend" is too large to have been wholly developed since Wisconsin times. In importance it is equal to that of Split Rock creek, which this hypothesis would regard as the older. It is true that the Big Sioux at present has the greater volume and so, though younger, might have the larger valley, yet it seems hardly possible that so large a valley can be younger than the last ice sheet. Until evidence to the contrary is presented it is easier to believe that the stream at the bend flows through

a pre-Wisconsin valley which was not wholly obliterated by the Wisconsin ice.

The valley at East Sioux Falls is more mature than at any point for some distance above or below. It is outside of the Wisconsin moraine, which here lies two miles to the west. Near the state line the moraine crosses the river, producing the gap mentioned. From this point south to Canton the valley has been partly filled in by morainic material.

On the course of the stream between Canton and Hudson the United States topographic map of the Canton quadrangle throws much light. The difference in the amount of erosion on the two drift areas makes it easy with the map to draw the line between them. It is clear that near Canton the stream leaves the margin of the Wisconsin moraine and flows through

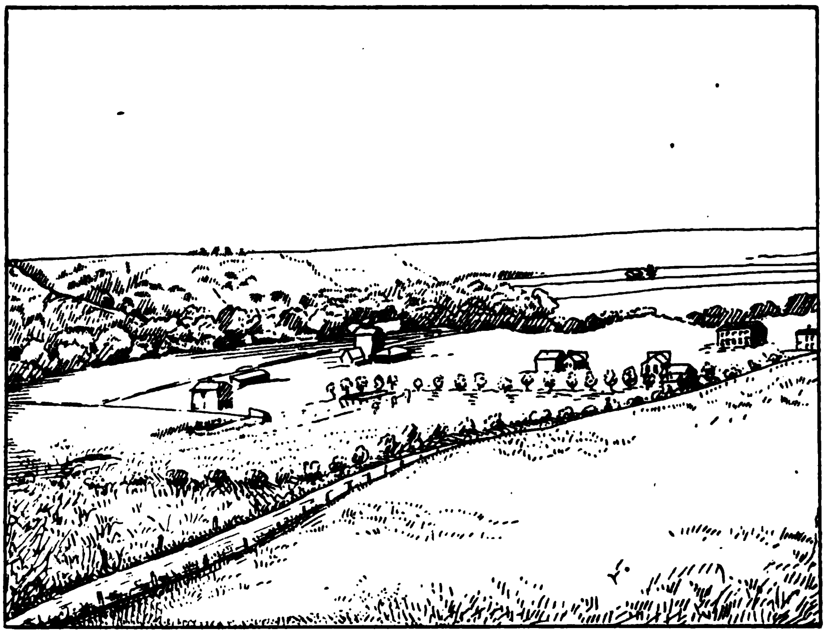


FIG. 14. Sketch of valley of the Big Sioux at Fairview.

the older drift. This portion of the valley is narrow, as the accompanying sketch made at Fairview shows, its slopes abrupt, and not covered with loess, but instead abundantly

bowlder strewn. Tributaries to the stream during this portion of its course are insignificant. The inference is that the stream which above followed the edge of the Wisconsin moraine, here, while the ice sheet still remained, found a new course across the older drift, probably following the course of some tributary of the Rock river till it united with that stream. This last inference is made necessary by the fact that the valley at Hudson is deep, cutting down through the Benton shale more than 100 feet, and now partly filled with drift. Below the point where the Big Sioux and Rock rivers unite, the valley is two miles wide and loess often covers the slopes to the gravel terrace, leaving no doubt that it is pre-Wisconsin. This valley is too large to be ascribed to the Rock river before the waters of the Big Sioux were added to it, or even to the work of these two after they united, and an explanation must be found in the belief that the tributary which here united with the Rock river, whose course was later appropriated by the Big Sioux, was a stream of some importance, yet small enough to necessitate the reworking and enlarging of its channel when its waters were augmented by those of the deflected stream.

ORIGIN OF THE LOESS.

The study of Lyon and Sioux counties adds something to the theories regarding the origin of the loess. The presence of the wind-polished bowlders already described, in the surface of the drift and projecting into the loess, favors the belief that the loess at least in many places is a wind deposit. Probably the weightiest argument in favor of the loess as a wind deposit is made by Professor Shimek, based on the fossils of the loess. He finds that the great majority of the loess fossils are shells of terrestrial species and he is able in many instances to duplicate the fauna of the loess with material now found living on the surface of the same region. "If the molluscs of the loess be used as an absolute measure of the amount of moisture occurring during loess times," he says, "then we

must conclude that Iowa was without streams, for practically no fluviatile molluscs occur in the loess, and that there were but few ponds in which aquatic molluscs found a favorable habitat.*" He adds that† "this, however, does not prove that the loess regions were entirely devoid of lakes and streams, but rather that the loess proper was deposited chiefly upon high grounds." A sheet deposit like loess occurs for wind-blown material if the area is evenly grass covered, while ridges result if the vegetation is in patches. The black specks of vegetable matter scattered through the loess of Lyon and Sioux suggest that there was a uniform grass covering which caught and held the fine dust particles. If the loess is an eolian deposit differences in behavior of the material may be expected and along streams where trees abounded ridges may be looked for, while in a prairie region an even mantle is the logical result.

Udden's‡ careful discussion of the mechanical composition of wind deposits, is of interest in connection with the loess. His table of approximate maximum distances over which quartz fragments of different dimensions may be carried by the wind is given below:

(1) Gravel (diameter from 8 to 1 mm.) a few feet.
(2) Coarse and medium sand (diameter 1 to ¼ mm.) several rods.
(3) Fine sand (diameter ¼ to ⅛ mm.) less than a mile.
(4) Very fine sand (diameter ⅛ to 1-16 mm) a few miles.
(5) Coarse dust (1-6 to 1-32 mm.) 200 miles.
(6) Medium dust (1-32 to 1-64 mm.) 1,000 miles.
(7) Fine dust (1-64 mm. and less) around the globe.

These figures of Udden are based on careful experiments and long continued observation. From them he deduces the statement that "different grades of material are so far separated from each other in the direction of the wind movement that even with considerable change in velocity the principal area of the deposition of sediments of one grade will not far encroach on that of the deposition of materials much

*Proc. Iowa Acad. Sci., Vol. VI, p. 103.
†l. c. p. 109.
‡The Mechanical Composition of Wind Deposits, Lutherian Augustana Book Concern, Rock Island, Ill.

coarser or finer." He points out the fact that the western plains and the Mississippi valley sustain the windward-leeward relation to each other, and that dust stirred up on the plains must be carried east by prevailing winds, and that part of it without doubt settles over the great central valley. The loess which is spread over most of the surface of this valley resembles atmospheric sediment in mechanical composition. That loess is certainly a wind deposit he does not affirm, yet he makes clear that the arguments against the eolian origin of loess based on the facts that it is uniform in texture and unstratified are in large measure invalid.

Opposed to these facts, is the statement of the Minnesota geologists that the loess seems to be practically limited by the 1500-foot contour. If this is true it would not necessarily force the conclusion that the loess is a water deposit though the fact would be most readily so explained. It would not be wise at present to venture an assertion in regard to the origin of the loess, but much of the evidence that has recently been collected bearing on this question, favors its eolian origin.

ECONOMIC PRODUCTS.

BUILDING STONE.

The Quartzite.—The supply of suitable building material is a matter of great importance to the many growing towns in Lyon and Sioux counties. Where elegance and permanence are desired the Sioux quartzite supplies the demand. The stone is of great value for building purposes, for paving and for curbing. Its value for paving is due to the ease with which it is shaped into square or rectangular blocks of convenient size, and to its hardness, which renders it almost indestructible even under the heavy traffic of the busiest portions of our great cities. It is not practical to reduce the face of quartzite pavers to the smoothness of vitrified brick, and this fact, taken with the greater expense of the quartzite blocks, renders impossible competition between these two kinds of paving material. Vitrified brick are rapidly and

rightly increasing in favor, yet there will always remain a steady demand for quartzite pavers for streets where truckage is heavy and constant. As building material it is often used in the rough in the vicinity of the quarries. Much of it is dressed, however, and in nearly every town in the two counties there are business blocks and churches built wholly or in part of quartzite, while a greater quantity is used for trimmings in brick buildings. Freight rates greatly restrict the use of the stone, but it is shipped in limited quantities as

FIG. 15. Dam on the Big Sioux at Hawarden. Ensign & Gordon's mill.

far as Chicago. Within this radius the quantity used increases as the source of supply is approached. Most of the quarries now operated are located in Minnesota and South Dakota. Imperfect railroad facilities are all that prevent Iowa from entering this market with her sister states. The stone in Iowa is in every way suitable for the purposes mentioned and an abundance of it is exposed on the surface. The outcrops in Iowa, however, are removed two miles from any railroad.

The Illinois Central and the Burlington, Cedar Rapids & Northern run at equal distances from the Iowa exposures, the first to the north, the second to the south. In view of the fact that vast quantities of the stone have direct access to the railroad not five miles away at East Sioux Falls and Rowena, S. Dakota, it does not seem practical at present to attempt an extensive development of the quartzite in Iowa.

CLAYS.

While the Sioux quartzite to a limited extent supplies the demand for building material there is an increasing demand for good brick in both counties. Very few are at present produced in either county, regardless of the fact that on account of freight rates from Le Mars and Sioux City, the nearest important producing points, they sell at from seven to eight dollars a thousand. This condition is not due to lack of suitable material, nor wholly to lack of effort to utilize the material, but rather to peculiar conditions in connection with the management and operation of the various brick plants that have from time to time been established.

Over the greater part of both counties the loess is from two to ten feet thick and in many places is available for brick. The presence of lime concretions is sometimes considered a hindrance, but in many localities concretions are not abundant, and even when present in numbers they do no harm if the material is thoroughly ground. At Sioux City loess having the same characteristics is successfully worked.

The earliest attempt at brick making in these counties seems to have been at Elm Springs in northwest Sioux county. About fifteen years ago two or three kilns were burned at this point. The material used was glacial clay and the fuel was wood. The product, as might be expected, was not uniform and the manner of production laborious and expensive. At Orange City the plant of the Orange City Brick company began operations in 1895 and ran only one year. An updraft kiln was used and 500,000 brick were burned that are still being sold. Five thousand repress brick were made with

a simple hand machine. Loess was used and but little effort was made to remove or crush the concretions and the appearance of the brick was thereby marred to some extent, interfering in a measure with their sale. The proprietors state that in their opinion a down-draft kiln, permitting the use of slack coal, could be made to pay. Differences of opinion on the part of the owners have prevented the use of the plant of late years. The price obtained for brick was from seven to eight dollars per thousand. A brickyard was established at Alton in 1893 which ran irregularly for three years. At the end of that time the machinery was sold. An up-draft kiln was used and a United States dry press with a capacity of 10,000 a day. Loess was used which is reported as free from concretions. Brick sold at from seven to nine dollars per thousand. Former owners of the plant report that the trouble was in the management. Those consulted reported that they thought, with proper kilns, presses and management a factory at that point would succeed. As formerly handled it was impossible to compete with Sioux City.

At Beloit the J. A. Smith brickyard was for some time in operation. Loess, and to some extent an underlying drift clay, was used. The clay was first washed through a screen to remove the concretions. It was afterward plugged by a wheel, moulded by hand and burned with wood in an open kiln. A good red brick is said to have been produced which found a ready market.

The brickyard at Hawarden promised success in every way before it burned in 1895. From a small plant working loess by hand it had gradually developed into a large establishment using the modern devices for brick making. An excellent exposure of Benton shale was located and at the time of the fire this was being made into an excellent grade of brick. Much of the product of this yard is at present in the buildings and pavement of Hawarden, and public opinion regards it as in every way satisfactory. The market was good and prospects for a large business excellent when the factory burned. The

loss amounted to $10,000, with an insurance of $2,000. The present owners are not in a position to invest further and in the fall of 1899 an effort was being made to sell the remaining machinery. The selenite in the shale is not in quantities sufficient to injure in any way the quality of the brick, which are hard and of a clear yellow-red color.

Orton & Son, during the summer of 1899, opened a yard at Maurice. Loess is used which at the point of excavation is twelve feet thick and wholly free from sand and concretions. It overlies a sandy loess which contains considerable lime. A "Little Wonder" side cut machine, manufactured by the Walrus Mfg. Co., Elkhart, Ind., is used. It has a capacity of 25,000 in ten hours. The bricks are dried in sheds without artificial heat and burned in simple up-draft kilns. Four kilns of 25,000 each have been burned and the product is very satisfactory. The bricks are smooth, hard and of good color.

Summing up the experiences of Lyon and Sioux counties in brick making, it is evident that the same material is present that is worked successfully at Sioux City. A little more care must be taken to find localities where the loess is free from concretions, or else to crush them, but loess without lime has been located in many places. Experience in building and handling kilns so far has been the main thing lacking. On account of freight rates the local producer is given control of an excellent market, and with fuel nearly as cheap as at Sioux City the field is a promising one for investment.

CEMENT.

The rapid increase in the use of Portland cement in this country has led the Iowa Geological Survey to carefully determine whether suitable material is not present in our own state for its manufacture. At present a large percentage of the cement used in northwestern Iowa is the product of the Yankton mills. Among other samples submitted for expert analysis was material from the limestone in the Benton of the exposure south of Hawarden. The report on these Hawarden samples shows that while the material is soft and could be

easily worked it is too low in lime for cement purposes. Purer material would have to be added to render it available.

An analysis of the Hawarden limestone is as follows:

Insoluble	21.92
SiO_2	.75
Fe and Al. oxides	6.68
$CaCO_3$	64.30
$MgCO_3$	5.38
	99.03

The insoluble matter consists of clay.

There is no considerable supply of purer material in the neighborhood and in view of the more favorable conditions elsewhere in the state it would be impossible to look to this locality for cement material. A more complete discussion of the nature of Portland cement and the conditions necessary for its successful production will be found in other reports of the Geological Survey.*

GRAVEL AND ROAD MATERIALS.

The gravel terraces of Rock river and the Big Sioux yield vast quantities of valuable ballast to the railroads in Lyon and Sioux counties. In the previous discussion of these terraces, points at which gravel is being taken for railroad purposes have been noted. Gravel in equal abundance may be counted on as occurring at any point near these rivers in both counties. Sand for building purposes is at times found associated with these gravels. In northeastern Lyon county the knobs of the Wisconsin moraine yield an abundance of gravel that is chiefly used for road improvement. The loess that is nearly everywhere found on the surface is itself a valuable road material. It dries quickly and after drying is firm and compact. To one traveling with horse or wheel in unsettled weather the change from the loess country to the Wisconsin drift is striking and decidedly in favor of the loess. Where the roads need artificial stiffening, as on the alluvium of bottom lands, the material is usually at hand in the gravel terrace.

*Iowa Geol. Survey, Vol. VIII, p. 335.

WELLS.

The gravel layers in the drift yield an abundance of water for farm purposes. Water is obtained at depths varying from thirty to two hundred feet. Such wells frequently yield 150 barrels per day. A larger flow may be counted on if the wells are continued through the drift and shale to the sand and sandstone that underlie them. This requires for wells on the upland a depth of 400 to 550 feet. Wells penetrating the Dakota sandstone frequently yield 100,000 gallons in twenty-four hours. The water rises in the wells to within 100 feet of the surface. For reasons discussed in connection with the Dakota sandstone, flowing wells from this formation are hardly possible. Small flowing wells from the drift may be obtained but it is impossible to predict localities where they may be found.

COAL.

The chances of finding coal in either county are very few. The Cretaceous of this region is not a coal producer. Under the Cretaceous there may be coal measures in the Carboniferous strata, but the region is outside of the Carboniferous area that so far has proved productive. Careful drillings were made with the best machinery and by experienced and reliable men, between Chatsworth and Hawarden, and while a number of lignite veins were developed in the Cretaceous nothing of value was found.

GAS.

While drilling for water in Tp. 99 N., R. XLV W., Sec. 34, Sw. ¼, in Tp. 99 N., R. XLVII W., Sec. 9, Sw. ¼, and in the vicinity of Doon, in three wells Mr. M. E. Layne encountered gas or air, which when the well was closed developed a pressure of twenty pounds per square inch. The gas was met with in the drift at depths varying from 180 to 290 feet. When the wells were cased the flow ceased. The gas was not inflammable and is said to have had a disagreeable odor. Beyond these points its nature was not determined. To one

of these wells a steam whistle was attached and allowed to blow for two days. The gas seems to have no economic value and the supply would probably soon be exhausted. It doubtless has its origin in decaying vegetable matter in the drift, possibly between two drift sheets.

WATER POWER.

The bed of the Big Sioux throughout its course along the western boundary of Lyon and Sioux counties has a slope of three feet per mile. It is a stream of considerable volume and, therefore, furnishes valuable power. At Hawarden, Ensign & Gordon's grist mill, by means of a seven-foot dam, obtains fifty-horse power from two turbine wheels. For two years they have been able to run without intermission, though at times have been troubled by scant water supply during August and September. The water is set back by the dam a little over two miles. They report no trouble from ice. At Fairview, S. Dak., just across the river from Elm Springs, Iowa, A. Spencer & Co. operate a flour mill and use thirty-five-horse power which they obtain from two turbine wheels and a dam giving a head of eight feet. They report that during nine months they have plenty of water and often during the entire year. At Beloit and Klondike there are similar mills operating under practically the same condition.

While the slope of Rock river is sufficient to furnish a good head of water with a dam of very moderate height, its volume is not sufficient for milling purposes during the summer months.

SOILS.

The soils of these counties may be classified as loess, drift and alluvium. The drift is practically confined to a few square miles in northeastern Lyon county. The loess covers the remainder of the surface except along the rivers where it is replaced by alluvium. The maps accompanying this report indicate fairly the location of the three soils, the gravel trains along the streams being alluvium covered.

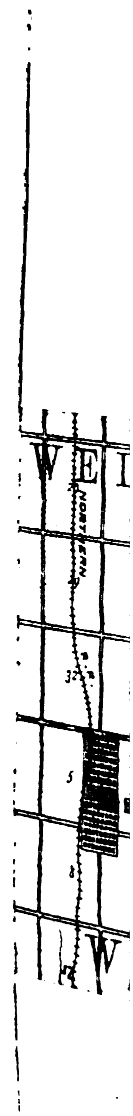
The alluvium is very fertile and bears abundant crops. It is so thoroughly drained by the underlying gravel that it is particularly productive during wet seasons and for the same reason suffers first during times of insufficient rainfall.

The loess-covered country is an ideal farming region, favored alike by drainage and soil. It yields abundantly and without fail crops of wheat, oats, rye and corn. Indeed, of the grains and grasses nothing appears to be excluded on account of the nature of the soil. The loess readily absorbs moisture and holds it for a long time, never bakes hard, and is always mellow and easily cultivated.

The drift of northeastern Lyon county furnishes a clay soil of great strength and fertility. The outwash region is particularly a region of beautiful farms, with level fields, yet free from ponds and waste land. The bowlders on the surface of the drift are nowhere abundant enough to interfere with cultivation.

ACKNOWLEDGMENTS.

Thanks are due Mr. H. F. Bain for much assistance and advice in the preparation of this report. Professor Calvin identified all of the fossils collected by the writer and on his determinations some of the more important results of this report depend. Mr. M. E. Layne of Rock Rapids furnished accurate and valuable well data and gave the results of his observations in regard to the depth of the drift. Professor Shimek added much to the interest in problems associated with the loess. Very many persons in Lyon and Sioux counties generously contributed information that was of prime importance in preparing the report.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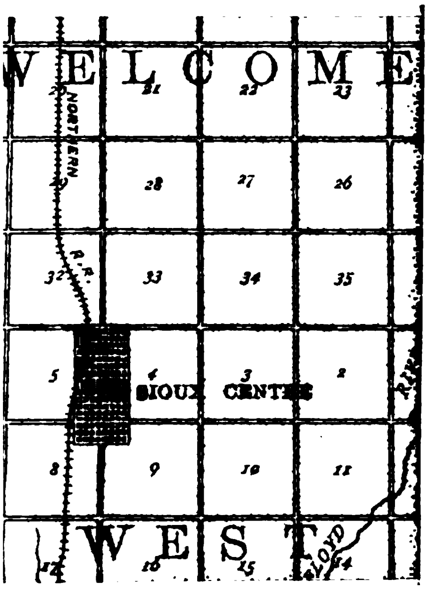
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THE FLORA OF LYON COUNTY.

BY B. SHIMEK.

The geographical position of Lyon county, its proximity to the dry western plains, its altitude and topography, and the fact that it is the only county in the state containing exposures of crystalline rocks (Sioux quartzite), make it one of the most interesting counties in the state from a botanical standpoint, for these varied conditions naturally have their influence upon the flora, which for its relationship looks rather toward the high dry western plains than toward the more moist prairies and forest regions to the east. For this reason a somewhat detailed report upon the flora may be of interest.* The surface of the county is for the most part a rather high prairie, which in the vicinity of the rivers becomes more rolling or quite rough, especially in the western part. No extensive swamps, or ponds or lakes are found. The Rock and Little Rock rivers are the only streams within the county that approach the dignity of rivers, and the Big Sioux, the largest stream, forms the western boundary of the county.

The greater part of the county is tillable. The river valleys are alluvial, and in some places somewhat sandy. The prairies are covered with a good black loam, the subsoil being loess clay in the southern part of the county and drift clay to the north. The latter makes quite as good a soil as the

*The observations herein recorded were made during three seasons in the months of June, July and August, and notes upon woody plants, etc., were also made in January. The vernal flora was not studied.

former, except on knolls and ridges where there is occasionally an excess of sand and gravel. The poorest soils are found in the western part of the county, in the hilly country bordering the Big Sioux river. Here in many places, especially on southerly slopes, the surface is gravelly and the soil is unproductive. The Sioux quartzite exposures in the extreme northwest corner of the county present a number of interesting botanical features.*

Upon and adjacent to them are found several species of plants which have not been found elsewhere in the state, such as *Opuntia fragilis*, *Potentilla pennsylvania strigosa*, *Euphorbia obtusata*, *Artemisia frigida*, *Aphyllon ludovicianum*, *Schedonnardus texanus*, *Buchloe dactyloides*,† *Woodsia scopulina*, *Marsilea vestita*, and several mosses and lichens. Other species found on the drier portions of the exposures are rare in the state. Such are: *Talinum teretifolium*, *Hosackia purshiana*, *Polygonum tenue*, *Oxytropis lamberti*, *Chrysopsis villosa*, *Pentstemon gracilis*, *Gilia linearis*, *Carex stenophylla*, *Selaginella rupestris*.

In addition to this the more shaded portions of the rock exposures, the adjacent streamlet and the more or less permanent pools of water with their outlying bits of marsh and moist prairie, the adjoining alluvial Big Sioux river valley with its mud flats, sandbars and moist shaded banks, the drier prairie hills bordering the river valley on the east, and the not remote cultivated fields on the broad upper terrace of the river valley, all bring here together a variety of conditions scarcely to be found within any equal area in the state, and all this in a strip lying along the northern boundary of the state, and measuring scarcely two miles in length, and but a few rods in width. This area, as might be expected, contains a greater variety of plants than any other part of the county indeed but few species which belong to the county are not found within these restricted limits.

Aside from this the county offers but little variety in the conditions which determine the distribution of plants. The

*For the author's discussion of the flora of these exposures see the Proc. Iowa Acad. Sci., Vol. IV, pp. 72-77, and Vol. V. pp. 28 31.

†Professor Macbride now reports this from Osceola and Dickinson counties.

valleys of the larger streams present the usual alluvial conditions, the rough western part of the county with its rounded hills, capped with loess or drift clay, is in surface and flora like the dry loess hills along the Big Sioux and Missouri rivers farther south, while the greater part of the county is rather high prairie, with occasional gravelly knolls or ridges, and low marshy "draws." Each of these regions, of course, develops its characteristic flora.

The names of plants which are employed in the following discussion are, with few exceptions, those of Gray's Manual of Botany, sixth edition. These are chosen not because they are in all cases deemed correct, but because the manual is still the most widely used work on systematic botany in the state. This will make the list intelligible to a great number of those who have not followed the recent attempts at changes in nomenclature, while those who have done so will have no difficulty in understanding to which plants reference is being made.

NATIVE TREES AND SHRUBS.

So proportionately small is the forest area of Lyon county that in any account of the botany of the county the woody plants would stand among the last to be considered. But much greater importance must be attached to them when we seek in their distribution and habits the key to the solution of the problems of tree-planting which are of so much importance in the economy of the prairie regions.

Such natural groves as occur are practically restricted to the three larger streams of the county. They are found in part in alluvial valleys, and in part upon the lower slopes of the adjacent hills. Along some of the smaller tributaries are found small clumps of the willows *Salix amygdaloides* and *Salix discolor*, and of wild plum and white ash, but these can scarcely be called groves.

The finest natural grove is found in the southwestern corner of the county along that part of the Big Sioux river which flows westward toward Canton, S. Dak. The river here

approaches close to the high and broken bluffs on the south side, being separated from them only by a narrow strip of alluvial plain. For two miles these bluffs present a rugged face to the north, seamed and scarred by ravines and gullies which run back toward the higher crests to the south. Almost everywhere these northern slopes, as well as the narrow alluvial plain below, are covered with a well developed forest. On the alluvial plain soft maple, box elder, white elm and white ash are most common, basswood is abundant on the lower slopes, while on the higher slopes bur oak is the prevailing form. But in no place does the grove reach the very summit of the bluffs to any considerable extent.

Upon the lower slopes true arboreal conditions exist. Mosses and smaller species of flowering plants characteristic of wooded regions, are abundant, and springs flow from the base of the wooded bluffs. This is in reality the only place in the county where true forest conditions, as we understand them in the rougher eastern and southern sections of the state, exist. Here, too, are found practically all of the species of woody plants which are native to the county, and on the lower slopes and the adjacent flats they are quite as vigorous and thrifty as in more easterly forest regions. It is only on the higher, more exposed slopes that the stunted bur oak displaces all other trees, or rather, is alone able to gain a foothold. In these more exposed portions of the grove the surface conditions are quite different. The stunted trees, growing more stunted with greater exposure, are scattered, forming "open" groves. The intervening ground surfaces are in large part covered with tufts of grasses and other prairie plants, and there is an almost total absence of leaf mould, of moss-covered decaying sticks and logs, and of the masses of smaller vegetation so characteristic of deeper woods. Northward from the Chicago, Milwaukee & St. Paul railroad the bluffs on the Iowa side are still rugged, but as the river flows almost due south, they are here more exposed to the southerly winds, and consequently but few groves have developed, and

these are of the stunted, open type, chiefly in ravines and "pockets" below the crests of the hills, on the leeward side.

The alluvial valleys of the large streams present the usual conditions which prevail along prairie streams which are skirted with clumps and bands of timber. As compared with more typical alluvial valleys southeastward they show a smaller number of species of trees, the trees are more scattered with a lesser variety of small plants growing beneath them, and there are frequent encroachments of species from the adjacent prairies.

The native woody plants of the county may be divided into three groups according to habitat:

1. *Species of the alluvial lowlands.*—As noted, these are found chiefly along the larger streams, but straggling specimens of the species already enumerated may be found here and there along smaller streams.

The following species were collected:

Acer dasycarpum Ehrh. Soft Maple. Common.*

Negundo aceroides Moench. Box Elder. Common.

Populus monilifera Ait. Cottonwood. Common, but probably chiefly introduced.

Salix amygdaloides Anders. Black Willow. Common.

Salix longifolia Muhl. Sand-bar Willow. Common.

Salix cordata Muhl. Heart-leaved Willow. Not rare.

Salix missouriensis Bebb (?)† Missouri Willow. Not common.

Sambucus canadensis L. Common Elder. Quite common.

Amorpha fruticosa L. False Indigo. Quite common.

Cratægus coccinea L. Red Haw. Not rare.

Prunus americana Marsh. Wild Plum. Common.

Fraxinus americana L. White Ash. Common.

Celtis occidentalis L. Hackberry. Common.

Vitis riparia Mx. Wild Grape. Quite common.

*All references to abundance of these woody plants are intended merely to convey a general idea of relative abundance of species in the restricted timbered area. The sum-total of any one species, of course, amounts to comparatively little because of the limited total forest area.

†Identified by Mr. Ball.

Viburnum lentago L. Sheep-berry. Not rare.

Salix discolor Muhl. Pussy Willow. Quite frequent.

The last six species of the preceding list also sometimes occur on banks and lower slopes; indeed this is true to a very limited extent of nearly all of the species in the list, the line of demarkation being by no means sharply defined. The intergrading of conditions naturally results in a mingling of species in any case, and this is intensified by the greater adaptability of some species to conditions which are not normal. For this reason in any system of plant grouping based on habitat it is practically impossible to draw sharp lines between the groups so defined.

2. *Species growing on protected banks and lower slopes.*— Most of these species also extend more or less into the lowlands. This group most nearly presents the species and conditions which characterize hilly woods eastward. This is especially true in the large grove already described, which is really the only typical locality in the county. The following is a list of the species:

Tilia americana L. Basswood. Common, especially in the large grove.

Ulmus americana L. White Elm. Common.

Ulmus fulva Mx. Red Elm. Rather common.

Ostrya virginica Willd. Hop Hornbeam. Frequent.

Fraxinus pubescens Lam. Red Ash. Found sparingly only near the Sioux quartzite exposures. Stunted forms of this and White Ash occasionally ascend to the crevices in the rock-ledges.

Gymnocladus canadensis Lam. Kentucky Coffee-tree. Quite common in the large grove.

Amelanchier canadensis T. and G. Juneberry. Found occasionally in the large grove.

Prunus virginiana L. Choke Cherry. Quite frequent.

Rosa blanda Ait. Smooth Rose. Not common.

Rubus strigosus Mx. Wild Red Raspberry. Not rare.

Xanthoxylum americanum Mill. Prickly Ash. Quite common, occasionally forming dense thickets.

Ribes floridum L'Her. Wild Black Currant. Not rare.

Ribes gracile Mx. Missouri Gooseberry. Very common locally, sometimes forming dense clumps.

Celastrus scandens L. Climbing Bittersweet. Not rare.

Euonymus atropurpureus Jacq. Burning Bush. Not common.

Ampelopsis quinquefolia Mx. Virginia Creeper. Quite common.

Menispermum canadense L. Moonseed. Not rare.

3. *Species of higher slopes and drier places.*—Stunted specimens of these species are likely to be found in straggling clumps almost anywhere on the prairies, especially on knolls and slopes, but they form no very considerable part of the prairie flora, being more common at the borders and in the vicinity of groves, or even extending into them.

Quercus macrocarpa Gray. Bur Oak. This is the most interesting tree in all the northwestern division of the state. It seems to be the pioneer of hard-wood trees, being the first of all trees to gain a foothold upon the knolls and slopes of the prairies. On the leeward side (*i. e.*, N. and N. E.) of the slopes the trees reach some size, though never forming the fine specimens which typify the species further east. As they ascend upward or reach out into less protected tracts they become more stunted and form the variety *olivœformis* Gray. Fruiting specimens not over a foot in height are frequently found in the exposed places. They have small leaves and small acorns, and sometimes several short stems are clustered on the same root. This species presents the best example of the stunting effect of summer winds upon the perennial plants of the northwest.

Rhus glabra L. Smooth Sumach. Quite common.

Rhus toxicodendron L. Poison Ivy. Common.

Salix humilis Marsh. Prairie Willow. Quite common.

Symphoricarpos occidentalis Hk. Wolfberry. This is the most widely distributed of the smaller woody plants, being found in almost all kinds of soils and situations. It usually grows in clumps.

Ceanothus americanus L. New Jersey Tea. Not rare.

Rosa arkansana Porter, the Prairie Rose, found commonly on the prairies may also be listed here.

CULTIVATED FOREST TREES.

The lessons which are taught by the native groves of Lyon county may well be applied in the cultivation of forest trees. The forest areas are small, it is true, and by far the greater part of the country presents a more fitting field for the study of prairie conditions, but the very fact that some trees do grow indicates that so far as general conditions are concerned they are not wholly unfavorable to the growth of trees. The native groves are uniformly found in valleys or on the north and east slopes of hills and knolls. The prevailing summer winds are southerly and southwesterly. They are strong and frequent, and being hot and dry they parch the exposed surfaces of the prairies. Both by their physical force and by their temperature and dryness, they check the growth of trees. In situations which are not exposed to these winds native trees grow readily and normally, but in exposed places, if developed at all, they are stunted and straggling. The Bur Oak, already cited, furnishes the best illustration of the effect of these winds.*

Exposure to the early spring sun on northern slopes, which hastens the early development of buds which are often nipped by late frosts, also serves to check or exterminate trees on southerly slopes.

Naturally the conditions which operate against the growth of native trees will also be unfavorable to the development of cultivated trees. To grow trees successfully in this county it is necessary that so far as possible they receive protection

*For a more detailed discussion of the effect of winds on growth of trees see the author's paper in the Proceedings of the Iowa Acad. of Sci., for 1899.

from the summer winds. There are really but two kinds of habitats in the county which are unfavorable to the growth of trees, namely the low, wet places in which the soil is "soured," and the gravelly knolls and limited rock exposures. The remaining soils are suitable for the growth of trees, and there seems to be no special difference between the drift clay soils and the loess, the latter, of course, representing merely the finer parts of the former sifted out. In both of these soils trees will grow readily if properly protected. This is best accomplished either by planting on northern and eastern slopes where this is possible, or by growing the trees in mass, in groves and not merely in rows, and surrounding the groves with rows of Cottonwood. The Cottonwood is the best nurse-tree for this purpose as it grows readily singly or in rows,—indeed it will not grow well in groves, the inner trees usually becoming dwarfed and soon dying out, while the outermost row uniformly shows greater vigor and longer life. All other trees, however, do better in groves, which should be dense at first, and later as the trees grow larger, they should be gradually thinned out. While small the trees should be cultivated, and later mulched with straw. Too much straw near the trees, however, increases the danger from mice. The weeds should be cut before going to seed, and left on the ground. No stock of any kind should be permitted to enter the grove, as nothing so quickly destroys trees. It is better to raise trees from seeds where possible, or to plant small trees. Nothing is gained by planting large trees as these are usually severely checked in their growth by transplanting. In transplanting, the roots should never be exposed to the air or permitted to dry.

With our present knowledge it is safe to say that as yet no introduced forest trees have exhibited superiority over native trees. The Russian Poplar, which has been tried, is scarcely a success, and moreover is a tree of comparatively little value. The Catalpa freezes down and is not a success. The introduced White Willow (*Salix alba*) is of the usual doubtful value. The miles of willows planted by Jesse Fell in the vicinity of

Larchwood in 1873 are now generally considered a nuisance. The Russian Mulberry will answer for wind-breaks and hedge-rows, but has no superior value. Lombardy Poplars have long ago been declared worthless, and few appear in this county. Evergreens of various kinds have been tried, sometimes with success, but more frequently they have failed. In a general way it is safe to say that most evergreens will do quite well when protected by other trees in groves already established, but as pioneers they are scarcely to be recommended.

Probably the best coniferous tree is the European Larch (*Larix europœa*). It will grow in comparatively dry places, the fact that its leaves are deciduous (and hence it is not an "evergreen") no doubt being an advantage. It makes a fine tree, grows rapidly, and its long straight trunk makes desirable post timber. It is not uncommon about Larchwood, and its success has been amply demonstrated.

The Red Cedar (*Juniperus virginiana*), while rather difficult to start in the open, makes good wind-breaks, and, when established, grows well. It is more readily grown under the protection of other trees, but the bark is often attacked by mice.

The Scotch Pine (*Pinus sylvestris*) grows fairly well, though, like all other evergreens, it is hard to start. It does not, however, make a satisfactory tree in the end, becoming scrawny and unsightly after eighteen or twenty years. The Austrian Pine (*Pinus austriaca*) makes a handsomer tree than the preceding, and improves with age.

The Norway Spruce (*Abies excelsa*) and some of the western spruces have been tried, but only with indifferent success. The best evergreens may be found in the former Larchwood nursery, but here they received special care and were grown in a large grove under very favorable circumstances. But even here the White Pine (*Pinus strobus*) was not a success, and its cultivation in this part of the state seems almost impossible.

Arbor Vitæ (*Thuya occidentalis*) has been tried, but is no more promising than some of the preceding.

In individual cases evergreens have done well, but on the whole they are not adapted to open prairie country, and as they are difficult to start, their planting, excepting occasionally for ornamental purposes, is an unprofitable venture.

Deciduous trees fare better. This is probably due at least in part to the fact that the loss of leaves (partial in very dry seasons in summer, and complete in winter) results in the loss of the transpiring apparatus, and the consequent inability of the tree to throw off water during these unfavorable periods. The trees which are most widely cultivated are the Cottonwood, Soft Maple, Box Elder and White Willow, the last being introduced. These and other species are here considered separately.

Cottonwood (*Populus monilifera*). The chief value of this tree lies in its rapid growth and its ability to hold its own when planted in single rows, this fact making it of value around groves of other trees. Mr. Carter, who surrounded and quartered several sections of land in Allison township with cottonwood trees some twenty-two to twenty-five years ago, demonstrated the possibilities of this tree. Single rows of Cottonwoods, now grown to large size, give to several square miles of surface the appearance from a distance of a large forest, and within the area itself the protection from winds, and other advantages offered by timber tracts, are presented in a marked degree.

For extensive wind-breaks, and for nurse-trees (only on the outside of groves, however), it is the most valuable tree cultivated in this part of the state.

Box Elder (*Negundo aceroides*). This tree grows rapidly, and produces a dense growth in a short time. It is also easily cultivated. However, it does not produce a tree of lasting value, and could be displaced by the White Ash with profit.

Soft Maple (*Acer dasycarpum*). This tree grows rapidly and if grown in clusters forms good wind-breaks, but, as a permanent investment it is not of much value, its brittleness also making it undesirable.

White Willow (*Salix alba*). This is extensively grown in some parts of the county, chiefly for hedge-rows. It quickly forms a dense wind-break, but is otherwise scarcely desirable. With Cottonwood it may be used for the outer protection of groves.

A number of other species native to Lyon county, or common in not remote sections of the state, are suitable for cultivation, and in the end prove much more satisfactory than the four most commonly cultivated kinds. The following are among the best:

White Ash (*Fraxinus americanus*). This is undoubtedly in many respects the most satisfactory tree for cultivation for general purposes on our prairies. It forms a pretty tree, stands drouth better on the whole than any other of the species in this list, is not easily broken by the winds, and in the end produces wood of excellent quality, an item which should not be forgotten, for to the farmer upon the treeless prairies a piece of strong, durable wood, suitable for repairs, etc., is often a great desideratum. Horses, rabbits, etc., do not often gnaw the White Ash, nor is it frequently attacked by insects, and this gives it an additional advantage. It grows best in groves which are protected on the south and west. The chief objection which has been made to this tree is that it is of slow growth. This is true only during the first five to eight years. During these first years the Box Elder easily outstrips it, but is soon excelled by it, not only in quality, but in beauty and size. The fine Ash trees on the old Carter place in Allison township, the splendid groves belonging to the McGuire Brothers in Rock township, and numerous smaller groves scattered over the county, demonstrate the usefulness and desirability of this tree beyond a doubt.

Black Walnut (*Juglans nigra*). This valuable tree can be grown with success in this county. The great mistake, however, which has been made in most efforts thus far, is that the trees were planted in narrow bands or rows, and were exposed. This develops trees with short trunks and wide-spreading crowns which make but little headway, and in exposed places they soon die. If grown in groves, especially among older trees of other species, they grow readily and produce tall straight trunks. The ash and walnut may both be planted in old groves of the softer woods with the view of displacing them. Walnut seed is best planted in the fall, and should not be covered very deeply.

White Elm (*Ulmus americana*). The elm has not yet demonstrated its usefulness in this county. It does quite well, however, in groves where not exposed to the winds, and in such places makes a good rapidly-growing tree. Rabbits and horses, however, relish it, and often do much damage.

Bass-wood (*Tilia americana*). While this tree does not compare in value with some of the preceding, it makes a fine shade and ornamental tree, but must be grown in sheltered places.

Wild Cherry (*Prunus serotina*). This species is but little cultivated, but deserves greater attention. It seems to grow even in somewhat exposed places, but does better in groves. The Red Elm (*Ulmus fulva*), the Hackberry (*Celtis occidentalis*), and the Honey Locust (*Gleditschia triacanthos*) are also sparingly cultivated, but they scarcely equal the preceding species of this list in value, though they may be successfully grown. The Wild Plum (*Prunus americana*) when grown in thickets makes splendid wind-breaks, and should be more widely cultivated for that purpose.

The hard-wood trees such as Oaks, etc., can scarcely be grown to advantage until larger groves are established in which they may find necessary protection. Farmers might well begin to replace their groves of Cottonwood, Box Elder, Maple, etc., with White Ash, Walnut, and other more valuable

trees. The latter could be easily grown in the shelter of the old groves, and in the end would give quite as much protection, besides yielding valuable wood. They are slower growers perhaps, but since the old soft wood groves are established and give the farmer the needed protection, this is a matter of less concern than when the groves were first planted. In case a new grove is to be established it would pay to first set out soft-woods as nurses, and then mingle the more desirable species with them, or plant in alternating rows or groups.

NATIVE HERBS.

The native herbaceous plants are here roughly grouped according to habitat. No sharp lines can be drawn, of course, and it is intended merely to indicate the ordinary or most common habitat.

1. *Species of ordinary fertile prairie.*—Some of these species encroach on the dry slopes, while others extend into the wet low-lands.

Anemone patens var. *nuttalliana* Gray. Pasque-flower. Specimens were collected as late as June.

Ranunculus rhomboideus Goldie. Prairie Crowfoot. Not rare.

Delphinium azureum Mx. Larkspur. Common.

Sisymbrium canescens Nutt. Tansy Mustard. Common.

Astragalus caryocarpus Ker. Ground Plum. Common.

Petalostemon candidus Mx. White Prairie Clover. Common.

Petalostemon violaceus Mx. Rose-purple Prairie Clover. Common.

Psoralea argophylla Pursh. Silver-leaf Psoralea. Very common.

Psoralea esculenta Pursh. Pomme Blanche. Not rare.

Glycyrrhiza lepidota Nutt. Wild Liquorice. Not rare.

Potentilla arguta Pursh. Five-finger. Very common, often in rather dry places.

Cnicus altissimus L. Tall Thistle. Common.

Coreopsis palmata Nutt. Tickseed. Common.

Echinacea angustifolia D. C. Purple Cone-flower. Common.

Erigeron strigosus Muhl. Daisy Fleabane. Very common.

Helianthus annuus L. Sunflower. Locally common.

Helianthus maximiliani Schrad. Maximilian's Sunflower. Very common.

Lepachys columnaris T. and G. Prairie Cone-flower. Locally common.

Lepachys pinnata T. and G. Gray-headed Cone-flower. Common.

Liatris scariosa Willd. Blazing Star. Very common.

Prenanthes racemosa Mx. Rattlesnake-root. Not rare.

Silphium laciniatum L. Compass-plant. Very common.

Solidago speciosa var. *angustata* T. and G. Prairie Showy Golden-rod. Very common.

Asclepias verticillata L. Whorled Milkweed. Common.

Asclepias tuberosa L. Pleurisy-root. Common.

Asclepias speciosa Torr. Showy Milkweed. Not rare.

Acerates viridiflora var. *lanceolata* Gray. Green Milkweed. Not rare.

Phlox pilosa L. Downy Phlox. Locally very common.

Onosmodium carolinianum var. *molle* Gray. False Gromwell. Common.

Pentstemon lævigatus Sol. Smooth Beard-tongue. Locally common.

Juncus tenuis Willd. Slender Rush. Very common, also often in wet places.

Elymus macouni Vasey. Macoun's Wild Rye. Not rare.

Agropyrum repens Beauv. Couch-Grass. Common locally.

Agropyrum glaucum R. & S. Blue-joint. Very common.

Bouteloua racemosa Lag. Racemed Bouteloua. Locally common.

Stipa spartea Trin. Porcupine Grass. Very common locally.

2. *Species of dry prairies, gravelly knolls*, etc.

Cerastium nutans var. *brachypodum* Eng. Short-stalked Chickweed. Locally common.

Silene antirrhina L. Sleepy Catch Fly. Common.

Linum sulcatum Rid. Wild Flax. Locally common.

Oxalis violacea L. Violet Wood-Sorrell. Not common.

Polygala verticillata L. Milkwort. Not common.

Vicia americana var. *linearis* Wat. Vetch. Occasional.

Hosackia purshiana Benth. Locally common. Native?

Amorpha canescens Nutt. Lead Plant. Very common. Really a shrub.

Oxytropis lamberti Pursh. Loco-weed. Quite common locally in the western part of the county.

Cassia chamæcrista L. Partridge Pea. Common, introduced?

Potentilla norvegica L. Five-finger. Common.

Potentilla pennsylvanica var. *strigosa* Lehm. Hoary Five-finger. Rare, found only in the vicinity of the Sioux quartzite.

Œnothera serrulata Nutt. Evening Primrose. Common.

Œnothera biennis L. Common Evening Primrose. Common.

Opuntia rafinesquei Engelm. Prickly Pear Cactus. Reported from Lyon county by Professor Pammel.*

Pimpinella integerrima B. & H. Yellow Pimpernel. Common.

Kuhnia eupatoroides, L. False Boneset. Common.

Liatris punctata Hk. Blazing Star. Common.

Grindelia squarrosa Dun. Gum Plant. Not common.

Chrysopsis villosa Nutt. Golden Aster. Common.

Solidago rigida L. Stiff Golden-rod. Very common. The most characteristic plant on the dry hills.

Solidago missouriensis Nutt. Missouri Golden-rod. Common.

Aster oblongifolius Nutt. Aromatic Aster. Common.

Aster amethystinus Nutt. Amethyst Aster. Rare.

*Proc. Iowa Acad. Sci., Vol. III, p. 119.

Aster sericeus Vent. Silky Aster. Common.

Aster ptarmicoides T. & G. Upland White Aster. Locally common.

Helianthus rigidus Desf. Stiff Sunflower. Very common.

Achillea millefolium L. Yarrow. Frequent.

Artemisia caudata Mx. Wild Wormwood. Common.

Artemisia frigida Wild. Wormwood Sage. Rare.

Artemisia ludoviciana Nutt. Western Mugwort. Common.

Artemisia canadensis Mx. Canada Wormwood. Not common.

Lygodesmia juncea Don. Rush-like Lygodesmia. Common.

Specularia perfoliata A. DC. Venus' Looking-glass. Common.

Gilia linearis Gray. Narrow-leaved Collomia. Common in the vicinity of the Quartzite exposures.

Lithospermum hirtum Lehm. Puccoon. Common.

Castilleia sessiliflora Pursh. Downy Painted-cup. Not rare.

Gerardia aspera Dougl. Rough Purple Gerardia. Rare.

Pentstemon gracilis Nutt. Beard-tongue. Quite common.

Pentstemon grandiflorus Nutt. Large-flowered Beard-tongue. Very common on the gravelly banks and bluffs along the Big Sioux river.

Verbena angustifolia Mx. Narrow-leaved Vervain. Not rare.

Hedeoma hispida Pursh. Mock Pennyroyal. Common.

Hedeoma pulegeoides Pers. American Pennyroyal. Common.

Isanthus cœruleus Mx. False Pennyroyal. Rare.

Scutellaria parvula Mx. Small Skull-cap. Not common.

Plantago patagonica var. *gnaphaloides* Gray. Pursh's Plantain. Locally common.

Oxybaphus nyctagineus Sweet. Heart-leaved Umbrella-wort. Quite common.

Oxybaphus hirsutus Sweet. Hairy Umbrella-wort. Not common.

Polygonum tenue Mx. Slender Knotweed. Common only in the vicinity of the Quartzite.

Comandra umbellata Nutt. Bastard Toad-flax. Rather common.

Euphorbia glyptosperma Engel. Ridge-seeded Spurge. Not common.

Euphorbia marginata Pursh. White-margined Spurge. Occasional.

Euporbia obtusata Pursh. Blunt-leaved Spurge. Not common.

Tradescantia virginica L. Spiderwort. Common.

Allium stellatum Nutt. Wild Onion. Not rare.

Carex stenophylla Wahl. Involute-leaved Sedge. Common in the vicinity of the Quartzite.

Carex adusta (?) Boott. Sedge. Not common.

Carex cephalophora Muhl. Sedge. Not rare.

Carex pennsylvanica Lam. Sedge. Not common.

Carex straminea var. *brevior* Des. Sedge. Common.

Carex straminea Willd. Sedge. Not rare.

Chrysopogon nutans Benth. Indian Grass. Still common on native prairie.

Agrostis scabra Willd. Rough Hair-grass. Rather common.

Poa pratensis L. Blue Grass. Probably introduced in such places.

Bouteloua hirsuta Lag. Muskit Grass. Local.

Bouteloua oligostachya Torr. Muskit Grass. Common.

Buchloe dactyloides Engelm. Buffalo Grass. Found now only in the vicinity of the Quartzite exposures.

Andropogon furcatus Muhl. Beard Grass. Common.

Andropogon scoparius Mx. Beard Grass. Common.

Festuca tenella Willd. Fescue Grass. Local.

Hordeum pusillum Nutt. Little Barley. Quite common locally.

Koeleria cristata Pers. Quite common on unbroken prairie.

Panicum scribnerianum Nash. Scribner's Panicum. Not rare.

Schedonnardus texanus Steud. Not rare in the vicinity of the Quartzite exposures.

Sporobolus cuspidatus Torr. Rush Grass. Common.

Equisetum lævigatum Braun. Scouring Rush. Frequent.

3. *Species growing on rocks, in crevices*, etc.—These are found on the Sioux Quartzite.

Aquilegia canadensis L. Wild Columbine. Occasional.

Talinum teretifolium Pursh. Fame-flower. Common.

Opuntia fragilis Haw. Prickly Pear Cactus. Not rare.

Woodsia scopulina D. C. Eaton. Rocky Mountain Woodsia. Common on the Sioux Quartzite ledges near the Big Sioux.

Selaginella rupestris Spring. Not common.

Numerous mosses and lichens are also found on and near the Quartzite. The latter group is especially well represented, the rocks being in large part covered with numberless specimens of numerous species.

4. *Mesophytic species of wood and meadow.*—This group includes species which require an average amount of moisture, and in most cases prefer more or less shade. They are the species of our ordinary wooded tracts. (*a*) Species of deeper woods, moist banks, borders of thickets, etc.

Clematis virginiana L. Common Virgin's Bower. Common.

Anemone cylindrica Gray. Long-fruited Anemone. Not rare.

Siline stellata Ait. Starry Campion. Quite frequent.

Amphicarpæa pitcheri T. & G. Hog Peanut. Frequent.

Desmodium canadense D. C. Tick Trefoil. Common.

Geum virginianum L. Avens. Common.

Heuchera hispida Pursh. Alum-root. Rather belonging to the following group.

Solidago serotina var. *gigantea* Gray. Golden-rod. Common.

Erigeron philadelphicum L. Common Fleabane. Common.

Campanula americana L. Tall Bellflower. Common.

Apocynum cannabinum L. Indian Hemp. Not rare.

Hydrophyllum virginicum L. Water-leaf. Not common.

Pedicularis canadensis L. Lousewort. Not rare.

Laportea canadensis Gaud. Wood Nettle. Rather frequent.

Pilea pumila Gray. Richweed. Rather common.

Polygonatum giganteum Diet. Great Solomon's Seal. Occasional.

Smilax herbacea L. Carrion Flower. Not rare.

Elymus canadensis L. Wild Rye. Common.

Leersia virginica Willd. White Grass. Common.

Panicum dichotomum L. Forked Panicum. Common. A weed.

Asplenium filix-fœmina Bernh. Spleenwort. Local. (*b*) Species of rocky, sometimes more or less shaded, banks.

Thalictrum purpurascens L. Purplish Meadow Rue. Frequent, but probably more common with the following group.

Oxalis corniculata var. *stricta* Sav. Yellow Wood-sorrel. Very common, and occurring in a variety of habitats.

Senecio aureus L. Squaw-weed. Common.

Ellisia nyctelea L. Quite common.

Ipomœa pandurata Mey. Wild Potato-vine. Occasional.

Parietaria pennsylvanica Muhl. Pellitory. Locally common. (*c*) Alluvial species, growing near streams and ponds. Most of these species also commonly occur on the borders of wet prairie meadows.

Ranunculus abortivus L. Small-flowered Crowfoot. Common.

Viola palmata var. *cucullata* Gray. Common Blue Violet. Quite common.

Echinocystis lobata T. & G. Wild Balsam Apple. Common in low woods.

Cryptotænia canadensis D. C. Honewort. Not rare.

Galium aparine L. Goose Grass. Common.

Galium triflorum Mx. Sweet-scented Bedstraw. Common.

Artemisia biennis Willd. Wormwood. Common.

Eupatorium purpureum L. Purple Boneset. Not rare.

Helianthus tuberosus L. Jerusalem Artichoke. Not rare.

Helenium autumnale L. Sneeze-weed. Common.

Rudbeckia laciniata L. Cone-flower. Common.

Silphium perfoliatum L. Cup Plant. Common.

Vernonia fasciculata Mx. Iron weed. Common.

Steironema ciliatum Raf. Loosestrife. Common.

Gerardia tenuifolia Vahl. Slender Gerardia. Common.

Scutellaria lateriflora L. Mad-dog Skull-cap. Common.

Polygonum ramosissimum Mx. Bushy Knot-weed. Not rare.

Humulus lupulus L. Common Hop. Common.

(*d*) Species growing in open places in wooded tracts, but also running into the prairie.

Fragaria virginiana Mill. Strawberry. Common.

Solidago serotina Ait. Golden-rod. Common.

Aster lævis L. Smooth Aster. Very common.

Aster novæ-angliæ L. New England Aster. Quite common.

Helianthus grosse-serratus Martens. Saw-tooth Sunflower. Common.

Heliopsis scabra Dunal. Ox-eye. Common.

Scrophularia nodosa var. *marylandica* Gray. Rather common.

Monarda fistulosa L. Wild Bergamot. Frequent.

Sisyrinchium angustifolium Mill. Blue-eyed Grass. Not rare.

Hypoxis erecta L. Star-grass. Common.

Smilacina stellata Desf. False Solomon's Seal. Not rare.

(5) *Species growing in sandy places along streams.*

Strophostyles angulosa Ell. Wild Bean. Common.

Eragrostis major Host. Strong-scented Eragrostis. Common. Introduced.

Panicum virgatum L. Prairie Grass. Common.

Some of the species in the following group also frequently appear in sand, especially if it is mingled or covered with alluvium.

(6) *Species growing in swamps, or at least in wet places.* These may be roughly divided into those which manifest a preference for wet places, and those which are distinctly swamp-species.

(*a*) Species growing in localities which are more or less moist.

Anemone pennsylvanicus L. f. Bristly Crowfoot. Not rare.

Nasturtium palustre DC. Marsh Cress. Common.

Nasturtium palustre var. *hispidum* DC. Rare.

Nasturtium sinuatum Nutt. Water Cress. Frequent.

Stellaria longifolia Muhl. Long-leaved Stitchwort. Not common.

Lathyrus palustris L. Swamp Vetchling. Not common.

Penthorum sedoides L. Ditch Stone-crop. Quite common.

Rotala ramosior Koehne. Rare. Near Quartzite exposure.

Lythrum alatum Pursh. Loose-strife. Quite common.

Ammania coccinea Rottb. Rare. Found only near Sioux Quartzite exposures.

Cicuta maculata L. Water Hemlock. Frequent.

Asclepias incarnata L. Swamp Milkweed. Common.

Mimulus ringens L. Monkey-flower. Not rare.

Ilysanthes riparia Raf. False Pimpernel. Occasional.

Pedicularis lanceolatus Mx. Swamp Louse-wort. Not common.

Lycopus sinuatus L. Water Horehound. Common.

Physostegia virginiana Benth. False Dragon-Head. Not common.

Mentha canadensis L. Wild Mint. Common.

Teucrium occidentale Gray. Germander. Locally very common.

Acnida tuberculata Moq. Water-Hemp.

Rumex salicifolius Weinm. White Dock. Frequent.

Rumex altissimus Wood. Pale Dock. Common.

Polygonum acre H. B. K. Water Smartweed. Common.

Polygonum pennsylvanicum L. Smartweed. Common.

Allium canadense Kalm. Wild Garlic. Rather common.

Carex hystricina Muhl. Sedge. Quite common.*

Carex sartwellii Desv. Sedge. Not common.

Carex vulpinoidea Mx. Sedge. Common.

*The sedges mentioned in this report were reviewed by Mr. R. I. Cratty, of Armstrong, Iowa.

Carex trichocarpa Muhl. Sedge. Common.

Carex cephalophora Muhl. Sedge. Common.

Carex straminea Willd., *var.* Sedge. Not common.

Cyperus erythrorhizos (?) Muhl. Not common.

Cyperus aristatus Rottb. Quite abundant.

Cyperus diandrus Torr. Common.

Cyperus speciosus L. Rather frequent.

Alopecurus geniculatus L. Foxtail Grass. Common.

Calamagrostis canadensis Beauv. Blue-joint. Still very common on undisturbed prairie.

Muhlenbergia glomerata Trin. Drop-seed grass. Not rare.

Muhlenbergia mexicana Trin. Drop-seed grass. Common.

Spartina cynosuroides Willd. Tall Marsh-grass. Common locally.

Calamagrostis longifolia Hook. Reed Bent-grass. Quite common.

(*b*) Swamp species.

Sium cicutæfolium Gmel. Water Parsnip. Not rare.

Herpestis rotundifolia Pursh. Hedge-Hyssop. Found in and around the edges of pools in the vicinity of the Quartzite exposures. Rare.

Veronica anagallis L. Water Speedwell. Not common. With the preceding.

Juncus nodosus var. *megacephalus* Torr. Rush. Locally common.

Sparganium eurycarpum Engelm. Bur-reed. Not rare.

Alisma plantago L. Water-plantain. Common.

Sagittaria variabilis. Engelm. Arrow leaf. Common in spots.

Eleocharis acicularis R. Br. Spike-Rush. Common.

Eleocharis ovata R. Br. Spike-Rush. Rather frequent.

Eleocharis palustris R. Br. Spike-Rush. Quite common.

Eleocharis tenuis Schultes. Not common.

Scirpus atrovirens Muhl. Bulrush. Common.

Scirpus lacustris L. Common.

Scirpus americanus Pers. Not common.

Beckmannia erucæformis var. *uniflora* Scrib. Found only in streamlet near Sioux Quartzite exposure.

Scolochloa festucacea. Link. Not rare.

(7) *Aquatic species.*

These are of two kinds—those which are rooted in mud, etc, but remain submersed, and those which are floating. Both of course are restricted in their distribution.

(a) Species which are rooted, but submersed.

Ranunculus circinatus Sibth. Stiff Water Crowfoot. Not common.

Nuphar advena sit f. Yellow Pond Lily. Rare.

Nymphæa reniformis DC. White Water Lily. Rare.

Myriophyllum heterophyllum Mx. Water Milfoil. Not common.

Polygonum muhlenbergii Wats. Knot-weed. Locally common.

Ceratophyllum demersum L. Hornwort. Locally common.

Elodea canadensis Mx. Water-weed. Locally common.

Heteranthera graminea Vahl. Mud-Plantain. Not common.

Potamogeton amplifolius Tucker. Pond-weed. Rock river. Not common.

Potamogeton fluitans Roth. Pond-weed. Rock and Big Sioux rivers. Common.

Potamogeton pauciflorus var. *niagarénsis* Gray. Rock river. Not common.

Potamogeton pectinatus L. Rock river. Not rare.

Potamogeton zosteræfolius Schum. Rock river. Quite common.

Marsilea vestita H. & G. Found sparingly in pools on the Sioux Quartzite.

(*b.*) Floating species.

Lemna minor L. Duck-weed. Locally common.

Spirodela polyrrhiza Schleid. Common in a pond in the northwest corner of the county.

(8.) *Parasites.*

To the foregoing list should be added the following parasites:

Cuscuta arvensis Beyr. Dodder. On low prairie plants. Locally common.

Cuscuta gronovii Willd. Dodder. On weeds, etc. Not rare.

Cuscuta glomerata Choisy. Dodder. On coarse weeds. Locally common.

Cuscuta tenuiflora Engelm. Dodder. On shrubs and coarse weeds. Common.

Aphyllon ludovicianus Gray. Broom-rape. Two specimens only were found on the quartzite tract. Introduced, no doubt.

FORAGE PLANTS.

The prairies were formerly covered with good forage-grasses. These are rapidly becoming exterminated, but virgin prairie still produces a number of species in abundance.

Of the species already listed the following may be classed as still valuable: *Andropogon furcatus*, *Calamagrostis canadensis*, *Agropyrum glaucum* and *repens*, *Panicum virgatum*, *Elymus canadensis* (of some value) and *Kœleria cristata*. The following would be useful if they occured in sufficient quantities: *Chrysopogon nutans*, *Poa pratensis*, *Beckmannia erucœformis* var. *uniflora*, *Buchloe dactyloides*, and the three species of Gamma Grass (*Bouteloua*) which are of some use on poor lands.

A few species add to the bulk, but not much to the value of prairie hay. Such are: *Spartina cynosuroides*, *Muhlenbergia glomerata* and *mexicana*, *Alopecurus geniculatus* and *Leersia virginica*.

The yellow Fox-tail (*Setaria glauca*) a common weed, is of some value as fodder in stubble. The remaining grasses and the sedges are of very little value.

WEEDS.

Both introduced and native plants appear as weeds. Of the introduced forms the following were observed:

Mustard; Charlock (*Brassica sinapistrum* Boiss.). Very common in fields. It is said that sowing Millet in fields infected with it will exterminate this pest.

Pepper-grass. Two species, *Lepidium virginicum* L. and *intermedium* Gray, both probably introduced, are not uncommon, but they are not specially harmful.

False Flax (*Camelina sativa* Crantz.). Sparingly introduced, probably with flax.

Purslane (*Portulaca oleracea* L.). Not very common.

Alsike Clover (*Trifolium hybridum* L.). Sparingly introduced.

Horse weed (*Erigeron canadensis* L). A nuisance in waste places.

May-weed; Dog-fennel (*Anthemis cotula* DC.). Not in sufficient abundance to be harmful.

Hog-weed (*Ambrosia artemisæfolia* L.). Becoming more common and a nuisance in waste places.

Great Ragweed (*Ambrosia trifida* L.). Common, and becoming troublesome.

Marsh Elder (*Iva xanthiifolia* Nutt.). Becoming more common and growing very troublesome, especially on lower lands.

Cockle-bur (*Xanthium canadense* Mill.). Common and troublesome, especially on lower grounds.

Burdock (*Arctium lappa* L.). Not yet common.

Dandelion (*Taraxacum officinale* Web.). Not very abundant.

Sow-Thistle (*Sonchus asper* Vill.). As yet scarcely noticeable.

Prickly Lettuce (*Lactuca scariola* L.). Not yet common.

Black Nightshade (*Solanum nigrum* L.). Occasionally in lower cultivated grounds.

Ground-cherry (*Physalis pubescens* L.). In fields, etc.

Bindweed (*Convolvulus sepium* L.). Occasionally in cornfields.

Plantain (*Plantago major* L.). Becoming troublesome in lawns, etc.

Mullein (*Verbascum thapsus* L.). Not specially troublesome.

Neckweed (*Veronica peregrina* L.). Common in cornfields, etc., but insignificant.

Curled Dock (*Rumex crispus* L.). Not very common.

Black Bindweed *Polygonum convolvulus* L.). Quite common, and sometimes troublesome in fields.

Pig-weed (*Amarantus retroflexus* L.). Quite common in waste places.

Tumbleweed (*Amarantus blitoides* Wats.). Quite common, and somewhat troublesome.

Russian Thistle (*Salsola tragus* L.). Quite common. In barren places or gravelly slopes the plants are often quite small and simple-stemmed. The species has not become specially troublesome.

Lamb's Quarters (*Chenopodium album* L.). Common in waste places.

Foxtail (*Setaria glauca Beauv.*) Common.

Old-Witch Grass (*Panicum capillare* L.). Rather frequent.

A few other forms, presumably native, also occur as weeds and do not appear in the preceding lists. They are:

Maple-leaved Goosefoot (*Chenopodium hybiridum* L.). Not common.

Three-seeded Mercury (*Acalypha virginica* L.). Quite common in fields, etc.

Nettle (*Urtica gracilis* Ait.). Locally common, especially in rather low places.

Prostrate Vervain (*Verbena bracteosa* Mx.). A common weed in waste places. Probably introduced?

Hoary Vervain (*Verbena stricta* Vent.). Very common, and becoming a nuisance in pastures and waste places.

Blue Vervain (*Verbena hastata* L.). Rather common, especially in lower grounds, and becoming a weed.

Squirrel-tail Grass (*Hordeum jubatum* L.). A pernicious weed, now already troublesome locally.

Of the species already given in the preceding lists several may be classed as weeds. The following appear chiefly in

cultivated grounds or waste places: Wild Liquorice(*Glycyrrhiza lepidota*), Partridge Pea (*Cassia chamæcrista*), Daisy Fleabane (*Erigeron strigosus*), the wild sunflowers (*Helianthus annuus, H. maximiliani, and H. grosseserratus*), Yellow Wood-sorrel (*Oxalis corniculata* var. *stricta*), and Pleurisy-root (*Asclepias tuberosa* L.).

A much larger number of native plants encroach upon pastures.

The following interfere chiefly with pastures on rather dry grounds: Loco-weed (*Oxytropis lambertii*), Lead-plant (*Amorpha canescens*), Yarrow (*Achillea millefolium*), Tall Thistle (*Cnicus altissimus*), Stiff Sunflower (*Helianthus rigidus*), Stiff Golden-rod (*Solidago rigida*), Rush-like Lygodesmia (*Lygodesmia juncea*), White-margined Spurge (*Euphorbia marginata*) Evening Primrose (*Œnothera biennis*), False Gromwell (*Onosmodium carolinianum* var. *molle*), and Porcupine Grass (*Stipa spartea*). The Stiff Golden-rod is so common on the hills in the western part of the county that it is decidedly troublesome. The Loco-weed, the White-marginal Spurge, and the Porcupine Grass are dangerous to cattle, but fortunately are not so common as to cause apprehension.

In pastures upon grounds which are more or less moist the following may be troublesome: Sneeze-weed (*Helenium autumnale*), Cone-flower (*Rudbeckia laciniata*), Iron-weed *Vernonia fasciculata*), Swamp Milkweed (*Asclepias incarnata*), Germander (*Teucrium occidentale*), Smartweed (*Polygonum pennsylvanicum*), and the Slender Rush (*Juncus tenuis*.)

Most of the weeds herein enumerated can be exterminated by persistent cutting before seed is produced. Fire and the plow also render material assistance. Individual effort, however, counts for but little, and if weeds are to be subdued in any section, a joint effort to keep them down in the fields, in waste places, and by the roadsides, must be made by all landholders.

GEOLOGY OF OSCEOLA AND DICKINSON COUNTIES.

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INTRODUCTORY.

LOCATION.

The two counties, Osceola and Dickinson, which form the subject of the present dissertation, lie in the extreme northwestern region of Iowa, Minnesota bounds them on the north, and on the west but a single county, Lyon, separates Osceola from the Sioux river—in this latitude the western frontier of the state. By the authorities of the Survey these two counties have been grouped together because it was supposed that here the several problems to be investigated, topographic, geologic, biologic, would present common features, so that the proper discussion of one county would almost necessarily involve research within the limits of the other. This view of the situation, as will appear has been only in a measure justified. Dickinson county presents many features which ally it more closely with the region east and south, while Osceola and Lyon county ought rather to be united. But, in fact, no two of these counties, nor indeed any one, ought to studied wholly as a disconnected fragment. The whole northwestern prairie is a unit and although details must still be picked up, probably county by county, still any report, as the present, ought to be reckoned largely provisional, subject to such subsequent revision as will no doubt be possible when the future student comes to contemplate at once the entire section of which our two counties form but a narrow segregated part. Dickinson county is pre-eminently the county of lakes and well isolated kames; Osceola is an elevated plateau, in many places nearly level, in others affected by long southward winding, trough-like valleys, offering a system of constructional

drainage belonging to the original make-up of the country, and not resultant from the erosion produced by present streams, lost within such ample limits. In both counties the drainage is imperfect, peculiar, pre-determined in an unusual way, and therefore well worthy of our study. Nor is the topography less interesting because of but few types; the very plains and valleys, the kames and hills, are all the more wonderful because in origin withdrawn from the operation of ordinary causes, and requiring for explanation the introduction of external agencies which have to do with planetary, not to say cosmic, phenomena. The lakes of Dickinson county are almost the only natural features of the kind within the limits of the state. Their wonderful beauty as well as their unique position would seem to warrant special consideration, and we attempt a fuller description than has hitherto been given. The flora of the region likewise possesses its interesting features and is discussed at some length in the last chapter under the heading, Forestry Notes.

PREVIOUS GEOLOGICAL WORK.

The earliest mention we have been able to trace of this interesting region is found in the notes and journal of the celebrated Lewis and Clark expedition, 1803-6.* The redoubtable Clark in his notes relates how "the Ceuoux river passes through the lake Despree." There can be no doubt about that reference. But in the formal Journal under date of August 8, 1804, we find the interpreter, Durion, describing in connection with the same Sioux river "a large lake nearly sixty miles in circumference, divided by rocks which approach very closely, * * * it contains many islands and is known by the name of Lac d'Esprit."

Nicollet certainly saw this region of the state in 1838-9, perhaps in company with Fremont, and his report† not only names Minnewaukon or Spirit Lake, but accurately describes

*A History of the Lewis and Clark Expeditions, Elliott Coues, Vol. 1, pp 69-70.

†Report intended to illustrate a map of the Hydrographical Basin of the upper Mississippi river, made by J. N. Nicollet, published as House Document No. 52, Second Session, Twenty-eighth Congress, January 11, 1845.

it and for the first time gives it a place on the map of the world.* Considering the circumstances under which he worked Nicollet's map is wonderful, and his descriptions of the Coteau des Prairies are remarkably graphic.

Ten years after Nicollet, the famous David Dale Owen seems to have visited northwestern Iowa. His report‡ leaves it uncertain whether he personally investigated the lake country; but he includes it in his description of the Coteau and of the "knobby drift."

These men were pioneers in geologic science, and in the present sketch there will be occasion once and again to refer to them and to their work. Nicollet's map and Owen's report are classic beginnings which later students may seek to emulate but must not hope too easily to surpass.

The scope of Hall's effort in the work he was permitted to accomplish for Iowa did not include the northwestern prairies, then, because destitute of mineral wealth, held in less esteem. Dr. White, however, studied the prairie counties very carefully, made the first attempt to explain the lakes of Dickinson county, and has described and even figured the topography of Lake Okoboji.§

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of the region before us, for a prairie district, is remarkably varied; we have high mountain-like hills and ridges with corresponding but exceedingly irregular and non-continuous depressions; we have wide expanded lakes but no affluent, and sometimes no regular, effluent streams; we have long, winding, insignificant rivers, moving anon sluggishly in valleys extremely wide, and again similar currents

*Lewis constructed a map "compiled from the authority of the best informed travelers," copied in 1806 by Nicholas King, which was submitted to Jefferson, as it appears, with the Lewis and Clark Report. But this map was never published until 1887. On this map the "L. Dispre" appears located with a fair degree of accuracy. See Hist. of the Lewis & Clark Expeditions, E. Coues, Vol. 1, p. 221.

‡Geological Survey of Wisconsin, Iowa and Minnesota; Lippincott and Grambo, Philadelphia, 1852.

§Report on the Geological Survey of Iowa, by Charles A. White, M. D., Vol. I, pp. 70-73, and Vol. II, pp. 219-23, and 226-29.

hemmed in by precipitous hills through which chance has determined a tortuous and difficult escape; we have wide gravel-plains cut by the channels of recent surface-drainage, and sometimes broad, level meadows, dotted with pools, marshes and lakelets with no drainage at all. So peculiar is

FIG. 16. Knobby drift region of northern Iowa. After Owen.

the hill-country here described that it has attracted the wondering attention of every visitor from Nicollet to the latest summer traveler. Just such hills and valleys are seen scarcely anywhere else in Iowa, although the region around Clear lake already described in these reports furnishes in some respects a parallel. * But in Cerro Gordo county the region affected would seem less extensive although no doubt its ridges and hills constitute a similar and correspondent geologic boundary. Owen was so much impressed with the peculiar conformation of northern Iowa that he figured these singular hills. He called the formation the "knobby drift" and his sketch is so good that we have here reproduced it as affording a better idea of the topography in question than any photograph could possibly have done. † Owen's figure

* Cf. in the present series Iowa Geological Survey, Vol. VII. pp. 132-4.
† Owen, Geology of Wisconsin, Minnesota, and Iowa, p. 104.

illustrates, perhaps, some landscape in the Clear lake country, or, as he denominates it, "the Knobby Drift Region, sources of the Upper Iowa," but his description as well is very graphic and carries the knobby drift at least very near the area now under investigation. He says: * "After passing latitude 42° 30′, and approaching the southern confines of the Coteau des Prairies, a desolate barren, knobby country commences, where the higher grounds are covered with gravel and erratic masses, supporting a scanty vegetation, while the valleys are either wet and marshy, or filled with numerous pools, ponds, and lakes, the borders of which are inhabited by flocks of sand-hill cranes, which fill the air with their doleful cries, and where the eye may often wander in every direction toward the horizon, without discovering even a faint outline of distant timber.

"This description of country prevails for about three-quarters of a degree of latitude, and between three and four degrees of longitude, embracing the water-shed where the northern branches of the Red Cedar and Iowa, and the eastern branches of the Des Moines, take their rise."

The phrase "between three and four degrees of longitude," if we begin at the 93d meridian, which is east of the point sketched, will make Owen's description cover all the northern tier of counties as far west as meridian 96, west of our limits. However this may be, there is no question as to the presence of Owen's knobby drift in the territory we now study. By reference to the accompanying map it will be seen that this peculiar topography covers nearly, or quite one-half of our entire area. The southern line of demarkation is a tortuous one. Beginning east of Swan lake it extends west just north of the town of Superior, thence south and west to about the center of Milford township, then northwest, turning at a point north of Milford, west and a little south until it passes Pillsbury lake, thence northwest toward Harris, in Osceola

* Owen, Geology of Wisconsin, Minnesota and Iowa, pp. 35-6.

county, on west to include the Ocheyedan country, then northwest, vanishing at last as it passes the diminished kames of Wilson township. It will of course be noticed that this line includes all the larger lakes; small wonder that the curious conjunction of lakes and prairie-hills has long been the subject of popular remark. It must not be inferred that all the region included by the boundary just sketched is entirely given over to precipitous hills; within these limits are many areas comparatively level, in some cases almost perfectly so, wide meadows with lakelets and marshes, as well as many beautiful farms; but within the limits described and north to the state line, hills and mounds mark the topography as nothing else. Moreover the hills are somewhat associated in groups, gathered about centers where some especially lofty point seems to dominate all the rest. Thus we have the group north of Swan lake, for the most part a series of nearly parallel ridges running east and west. These ridges are much broken up of course, and nowhere continuous for any great distance, but their general trend is as described, and from their summits the most magnificent vistas lie revealed, especially northward where the villages of Minnesota dot a level prairie. Another group lies east of East Okoboji lake and centers near Prairie lake in a point 150 or perhaps 160 feet above the water level. Another group of hills of the most irregular character lies between Spirit lake and Okoboji and culminates in a high peak in the northeast corner of the Ne. ¼ of Sec. 1, in Lakeville township.

The hills about Diamond lake, those northwest of Silver lake, those of Fairview township in Osceola county, simply defy classification or description; they pitch toward every point of the compass, they are of every height and shape, they rise by gradual ascent and fall off by precipices so steep that the most venturesome animal would scarcely attempt descent; they enclose anon high tablelands, anon wide low valleys that open nowhere; they carry lakes on their summits and undrained marshes at their feet; their gentler slopes are beautiful prairies

easily amenable to the plough, their crowns are often beds of gravel capped with bowlders and reefs of driven sand.

The most remarkable of all these hills, a beautiful object in itself, and by far the most elegant illustration of its type, is the long time famous Ocheyedan* mound (Fig. 17). This is a

FIG. 17. The Ocheyedan mound, seen from the southwest.

prairie mountain, a precipitous knob or peak, rising at last abruptly from the general surrounding level. It is situate in the Sw. ¼ of the Sw. ¼ of Sec. 12 in Tp. 99, R. XL, W. on the east bank of the Ocheyedan valley, and about one mile southeast of Ocheyedan town. One hundred and seventy feet above the valley flood-plain, and at least twenty feet higher than any surrounding land, it has long been a landmark and is visible at their homes to hundreds of the citizens of Osceola county. The height above sea-level, as estimated from data furnished by railway surveys, is not far from 1,670 feet, one of the highest points in Iowa, its only rival the summit of the moraine in Wilson township northwest of Allendorf, which has probably about the same elevation.

*Pronounced O-chee-dan; Nicollet has this to say: "Otcheyedan—a name derived from a small hill, the literal meaning of which is 'the spot where they cry'; alluding to the custom of the Indians to repair to elevated situations to weep over their dead relatives."—Nicollet, Report of the Upper Mississippi River, etc., p. 27.

tion. The general trend of the mound is northwest-southeast, extended diagonally across forty acres. The extreme length is accordingly about one-third of a mile. The northwest face and the sides are very precipitous; the sides especially so, marvelously so when we reflect that we have no rocky core, nothing but loose material easily subject to erosion. Indeed the mound is a typical kame,* a pile of drift made up, if one may judge by the exposure on the northeastern face, of sands and gravel-beds alternately but irregularly laid, cemented anon by lime, more often by deposits of accumulating iron. Over the whole mound lie scattered bowlders some of large size, where granite, porphyry, Sioux quartzite and limestone are strangely intermingled. The width of the summit at its narrowest point is no more than twenty or thirty feet, but the surface slopes off so gently to the southeast that a wagon-road has been constructed from that direction, and it is possible thus to make the ascent with ease. The view from the mound-top is well worth the effort to obtain it; to the south and west the valley of Ocheyedan, wide and flat limited by the broad morainic ridge on which stands Allendorf and, farther west, the town of Sibley; to the northwest Ocheyedan town with low hills like a tumbled sea lost in the northern plain; to the northeast the same low swelling hills and hummocks to Harris and Lake Park, and so round again to the farthest southeastern limit, where once more the horizon melts to the unbroken level of the prairie. Two similar mounds lie immediately north of this one, and a third in the northwest quarter of section 4; one is immediately west of Rush lake; but these, though large and high, are unnoticed in presence of the "hill of mourning".

But the remaining half of the region we are studying possesses also topographical characteristics of peculiar interest. The ridge just mentioned, which extends diagonally southwest almost across Osceola county is, to one approaching

*A ridge or hill. Compare comb, that is, a ridge as of a house. The word seems to be Scotch and was first used by Scottish geologists to designate a mound or hill of glacial origin.

from the east, a very striking topographic feature. Through the greater part of its extent it presents toward the northeast an abrupt, almost precipitous face, which, in the latitude of Ocheyedan mound, is 150 feet above the valley lying before it. Two miles west of Ocheyédan station the bluff faces directly north, and along this face the railway climbs for the distance of about a mile on the way to Allendorf. After reaching the crest of the moraine the ascent still continues, and Allendorf station is sixty-six feet higher than Ocheyedan station, and so probably within thirty feet of the summit of Ocheyedan mound. As the surface continues to rise from Allendorf north and west, there seems little doubt that there are several points in Wilson township where the barometer will mark an altitude almost, if not quite, as high as that of the famous hillock. These high points are by no means necessarily hills, nor possibly at all recognizable to one passing over the county. One of them, at least, is a marsh of considerable extent and forms the source of the Little Ocheyedan creek. Others are broad fields sloping gently in all directions. At most the various points of the highland here described vary but a few feet in comparison with one another, and none of them fall short of the mound by probably more than fifteen or twenty feet.*

At any rate the ridge in question forms a water-shed, distributing in all directions save north. Eastward the waters join the Little Sioux, westward the Rock river and south the Floyd. To the passing observer the country seems perfectly flat, except as disturbed here and there by recent erosion or as marked by an occasional diminished kame; but the land really slopes everywhere gently to the west or southwest. The moraine is from six to ten miles in width and blends to the southwest into an entirely different topography, where the level is fully a hundred feet lower.

*It would be interesting once for all to settle this question of altitude, but the Survey was not in possession of the requisite instruments. From such data as are at hand the present writer concludes that the highest point in Osceola county, and this means the highest point in Iowa, is near the center of Wilson township, and has an altitude not far from 1,670 feet.

The land formation of the southwestern part of Osceola county is another region which, on account of topographic interest, deserves mention here. Beginning a few miles south of Sibley the erosion features of Otter creek valley, and indeed of nearly the whole of Gilman township, are strikingly unlike anything else of the kind seen in our present territory. In short the topography is erosional; not constructional, a fact which becomes more and more patent as one follows to the southwest the road from Ashton to Sheldon. The valleys are not always wider nor deeper, but they form a more plainly developed system, with tributaries again and again subdivided. In fact the drainage of the Ashton region is better than is shown anywhere else in either Osceola or Dickinson county.

But there is a third topographic peculiarity of this section which warrants reference and description. In various places on hillsides, and especially by the margins of the larger streams, there are peculiar deposits of gravel which now and then widen out into considerable plains. The most remarkable of these is seen in Dickinson county, immediately south and west of the town of Milford. Here we have a sandy, gravelly prairie, some two or three miles in width and reaching the southern boundaries of the county, following in general the course of the Little Sioux river, almost level save as affected by local erosion, without kettle-holes, and entirely destitute of those features which mark the level prairies in other parts of the county. As we shall see farther on, the gravel prairies owe their existence to conditions altogether unlike those which have operated elsewhere to create the level portions of this particular part of Iowa. Through this plain of gravel and sand the Sioux, or rather the "outlet," as the discharge from the lakes is called, has cut a deep but not wide channel. The mill-pond of old Milford occupies part of this erosion channel, and the mill-pond of the Okoboji Mills forms a continuation of the same depression. Farther south and west after the entrance of the Little Sioux the erosion has left on the west side of the valley a remarkable terrace (Fig.

3) which may be traced to near the middle of section 22. in Okoboji township. Farther down in section 33, just before the river leaves the county, the bluffs of drift approach each other very nearly; are within perhaps a half a mile of each other. Here the terrace is best displayed on the west

FIG. 18. Milford Terrace, seen from the east side of the Little Sioux.

side of the stream and is very marked, though narrow, a remarkable shelf, lifted at least fifty feet above the level of the present river.

Similar gravel trains or terraces are discoverable along the lower portions of Muddy creek, of Otter creek, and the Ocheyedan. Sometimes the formation is represented by a trace only; at other times it forms a bank more or less distinctly noticeable,—generally attacked by the farmers as a gravel-pit. It is to be noted that these terraces and gravel plains lie almost entirely outside the margin of the hill-country above described: are nowhere represented, except the kames, by anything more than a bank or trace within it. The sandy shores of Spirit lake must, however, be referred to again later on. They do not belong to quite the same category

as the stream terraces here described, although evidently made of the same materials.

The stream-valleys in these counties are in every way peculiar. Hardly one of them shows a history of simple continuous erosion. The gravel deposits just described indicate successive chapters in the story. The valleys have been eroded, filled up and eroded again. This is indicated plainly enough by the situation south of the hills. In the hill-country proper the valley is sometimes erosional, sometimes constructional. Let anyone interested compare, for instance, the two forks of the Little Sioux river, as these occur in the northern part of Dickinson county. The west fork is a tortuous steam, crossing meadows or winding among hills which it is still eroding, first on one side, then on the other; the east fork, especially in Diamond Lake township, lies chiefly in a wide valley which might easily have formed the basin of a great lake extending north and south. See particularly the view of the valley as seen from the northwest corner of section 32 in the township referred to. Or compare Dug-out creek, in Dickinson county, with Otter creek, south of Sibley, in Osceola county; the contrast could scarcely be greater.

The lakes, too, should be noticed in this connection. They lie in great depressions which are constructional, have no reference whatever to any drainage-system, at least of recent times. The long chain of lakes from Spirit lake south to the Little Sioux river, may have ever formed as now the channel of a southward moving stream, but the channel is not the creature of the stream; even the "outlet" owes to erosion but the later touches. The wide basin-like depression until lately used as the Milford mill-pond has suffered erosion on the western side but in its broader features seems to have been determined by other agencies. The surface of Lake Okoboji is more than forty feet below the Milford plain, while the surface of Minnewaukon or Spirit lake, although at present ten feet or more higher, is more than 100 feet below the highlands on either side of it from Superior almost to Lake Park. The

finest view of the topography of the lakes just mentioned is obtained from points along the highway in sections 22 and 23 in Center Grove township. The site of the church in the Sw. ¼ of the Nw. ¼ of section 23 is 150 feet above the level of the water of East Okoboji lake (September, 1899).

It will be seen from all this that the topography of the country we study is not explained by reference to causes now at work in the locality. No stream, no floods of storm-water, ever cut a valley which has no outlet, or created hills of every size and height with undrained valleys on every side. In fact it is difficult at first sight to see how any force whose action is known to students could bring about just the effects we here behold. The only agency to which appeal is made is that of moving and melting ice. These phenomena are glacial. They fix for us by their very irregularity the limits of some ancient glacier's action, the borders of its ebb and flow. That the glacier was here we know by the abundant drift, to be further on discussed; that it rested here is certain, else had all this drift been spread abroad, every "valley exalted and every mountain and hill made low," and the whole country reduced to the marshy plain so widely characteristic of the counties to the south and east, over which the glacier is understood to have accomplished its perfect work. The conditions before us are, therefore, morainic and are explainable only as that fact is kept constantly in mind. The margin of the glacier is never uniform either in situation or direction. It varies constantly, now extending, now retreating, often changing with each succeeding season. More than this, our problem is still further complicated in that our moraine is only quasi terminal; it is lateral or termino-lateral. It is probably terminal with respect to the ice-movement of any particular locality but lateral in its relation to the progress of the glacier as a whole. In many places we have probably the resultant of both movements, the effect produced by various forces acting in different directions at the same time, with results not unlike those caused by eddies at the border of some majestic river.

It must further be premised that the agencies in question were active in the same way over an area of very considerable extent, in which was found all needful room for the great diversity we have so far described. The Iowa glaciers were very wide and their moraines are proportionately broad. It need not therefore be a matter of surprise to find, as in the present case, morainic deposits spread over a width of nearly thirty miles. The entire hill-district above mentioned, in all its confused and tumultuous disorder, lies before us, the record of the lateral moraine of an ice-sheet once extending east and west from Osceola to Cerro Gordo county. In recent geologic literature the term Altamont has been applied to that particular part of any morainic deposit which marks the extreme limit of this glacier flow or thrust. In the case before us the wide ridge west of Ocheyedan river seems to be the Altamontane crest, marking the glacier's furthest western movement, a levee, a dike, behind which all subsequent recessions, cross movements, advances, eddies and retreats performed their marvelous work. The western limits of this ridge are difficult to define. The Little Ocheyedan drains its summit; beyond, the deposit gradually fades out of sight, so that it will require much closer investigation than has yet been given to define exactly where lies the ultimate boundary. In fact the ice itself seems to have thinned out at its very margin and to have carried with it a proportionately less amount of drift. This was spread beyond the summit of the ridge in varying thickness, sometimes in patches, and finally fails entirely. To the northwest the ridge widens and is less conspicuous; at the southeast it is much narrower and we may hope that its limits southward may be easily determinable, once the topography of O'Brien county becomes a matter of investigation.

THE LAKES.

The lakes of our region lie almost all in Dickinson county. Not that Osceola is destitute of similar topographic features,

but for some reason the peculiar conditions that resulted in lakes of size were developed farther east. Iowa lake in the northern part of Fairview township, extending northward into Minnesota, is the finest lake now seen in Osceola county. Rush lake, northeast of Ocheyedan, visible from the car win-

FIG. 19. A glimpse of East Okoboji seen through the ranks of young Bur oaks.

dows to travelers along the Burlington railway, is, as its name implies a great morass or marsh, covering altogether about a section of land. Similar swamps and lakes, but far smaller in extent, are not infrequent throughout all the morainic hill-country, especially north and east. Many of these hitherto marked on the map have been successfully drained and are now cornfields and meadows. But in Dickinson county the lakes are the features of the topography, many of them deep enough to promise permanency, and several so large as to have long attracted popular attention by their beautiful blue waters and the charming outlines of their shores. (Fig. 5.) Minnewaukon or Spirit lake, is as we have seen, historic, nay, is it not prehistoric? Even for the

red man these beautiful gems of the prairie had name and fame. He hung them around with legends of his own and named them in his own poetic, mystic fashion. Okoboji, place of rest; Minnetonka, great water; Minnewaukon, lake of demons, *lac d'esprits*, were every one apparently familiar to all the tribes and nations of the Sioux, and were doubtless known by name at least to all the eighteenth-century trappers and *voyageurs*. Okoboji, evidently distinguished by the red man, was by white explorers generally reckoned part of Spirit lake, and is so entered on the earlier maps. The two bodies are in fact part of a remarkable system extending in chain-like fashion for twenty miles or more in Iowa and probably almost as far in Minnesota. Nevertheless, the greater lakes have now no natural connection with each other; they are in general quite unlike and have, in some details at least, a different geological history. In all cases the water level seems dependent entirely upon rainfall. The few springs discoverable are small and insignificant, while of affluent streams there are practically none; none at least that bring in perennial waters. The overflow of the Minnesota lakes, it is claimed, reaches our Spirit lake, and certain smaller lakes to the west and north are also on occasion tributary. But all the lakes, whether in Iowa or Minnesota, are subject to similar fortune. In rainy seasons full, they send their waters to the common outlet; in drier years there is no surplus and the outlet fails. In fact the lakes are each and all simply great pools left on the surface by the retreating glacier, marking points where the ice was somewhat thicker or the amount of detritus carried somewhat less abundant. They owe not their existence to erosion; no recent change of level has formed an outlet for their waters; such as they are, such were they when the latest geologic epoch closed. The present form and condition of the outlet would not suggest that the principal lakes, at least, have ever been much deeper than at present. The outlet valley is largely constructional and while there has been erosion, considerable in the vicinity of

Milford, still erosion has not in time past much affected the level of the lakes, does not at the present day seem to affect them at all. Those familiar with the situation for the last four or five decades assert that Spirit lake had formerly a natural outlet southward. There is no sign of it at present. On the other hand the out-thrust of the ice from winter to winter has tended to form a species of dyke almost entirely around the lake, especially along its sandy beaches, and this alone would seem to have been sufficient to close up any connection, slight and shallow at best, between Spirit lake and the waters south of it. At any rate there is along the south shore of Spirit lake a pronounced terrace, which is natural and due to the causes mentioned. There are, however, evidences, chiefly afforded by terrace-construction, that the water level in the lake has been higher in days gone by than now, perhaps ten feet higher. In such event there would be an overflow southward. Probably the level of the lake has oscillated through the centuries. With a succession of dry seasons the water would become so reduced that out-flow would cease entirely. The sand pushed up in winter by the ice would then form a dam higher and higher and which at length only a very considerable rise in the waters of the lake could surmount. Then probably some exceptionally rainy season would wash out the obstacle and again reduce the level of the lake, making possible again the construction of the dyke. In the maintenance of the barrier vegetation very much assisted. To-day various aquatic plants hold the shallower parts of all the lakes in possession undisputed and greatly check the movements of their waters. In fact by reason of abundant vegetation many of the smaller lakes are now in danger of being completely filled. The plants, many of them rooted to the bottom, at once absolutely prevent erosion, and at the same time hold all solid matter coming in from whatever source from without. For this reason the general outlet of the system, the south end of the south Gar lake, is not

deepening, but seems to be actually rising year by year. But it is time we should describe the lakes more in detail.

Minnewaukon or *Spirit lake*, the largest body of water in Iowa, occupies the greater part of the township of the same name. Its extreme length from north to south is a little more than four miles, in Iowa. The extreme width is about the same, but owing to irregularity of contour the area is not more than ten square miles, while the circumference is nearly sixteen. The depth of the lake is said to be thirty feet; the bottom, so far as can be learned, is almost even, so that from the deepest part to the shores the diminution in depth is remarkably gradual.* The shores are for the most part comparatively low, the water-line sandy, affording unlimited beach. Hard by on the west lie Marble lake, Hottes lake, and Little Spirit lake, separated by only the shortest distance from the main body of water, but draining one into the other and north—at length, however, tributary to Spirit lake. Those interested have in recent years cut a channel to bring Little Spirit lake and its congeners into more direct communication with the larger water, apparently with small success. In dry years no lake has anything to spare. Strangest of all, in the middle of the series, in the south half of section 17, lies Sunken lake, distant from Spirit lake only a few rods, and parted from it by a wall of drift some twenty or thirty feet high and at its summit scarcely a rod in width. So abrupt are the shores and so peculiar the situation that common rumor asserts the lake a matter of recent formation; some people even declare that so lately as twenty years ago trees stood where now the water is ten feet deep. The name Sunken lake records the popular estimate and explanation of the remarkable phenomenon. It seems probable, however, that Sunken lake is as old as any of the others, and while a most remarkable bit of topography, sufficiently wonderful to demand, even peremptorily demand, an explanation, yet is it

*These particulars are from the reports of fishermen and boatmen about the lake.

quite in harmony with its entire surroundings, and not without parallel in many only less conspicuous cases. For instance, on the east side of East Okoboji lake, in the southwest quarter of section 15, Center Grove township, there are two small lakes even nearer the principal lake than in the case we have just considered and similarly walled off from the greater body of water by a pile of drift. Similar situations on a small scale may be pointed out in every part of Dickinson county. The only explanation is the unevenness of the lower surface of the ice-sheet which rested here, advanced no further, and as it melted retreating ever farther and farther northward, left behind, perchance as blocks of ice, these pools of clear, fresh water. Sunken lake may then represent an ice bowlder; this seems more probable since its walls are steep, unbroken on every side.

Okoboji.—South of Spirit lake lies Okoboji, in its two sections stretching somewhat in the form of the letter U, open to the north, partly in Center Grove, partly in Lakeville township. West Okoboji, which represents the western side of the U, lies almost wholly in Lakeville.* This is by many estimated the most beautiful water in the series. Its greater depth, more picturesque winding shores give it some advantage over Minnewaukon, although the latter shows the greater expanse of water. West Okoboji lake, or simply Okoboji, as it is commonly called, extends nearly six miles in greatest length and almost three at the point of greatest breadth. The greater portion of the lake is, however, narrower, so that the total area does not exceed seven square miles, while its irregular contour measures nearly eighteen miles, as platted. The depth of the lake varies very much at different places and is variously reported. The bed of the lake probably resembles the topography of the adjacent country; it has its hills and its valleys. There seems no reason to doubt that there are many places

*West Okoboji seems to have been named Minnetonka by the Sioux. Okoboji then applied to what we now call East Okoboji. Minnetonka was and is the name of a somewhat celebrated lake in Minnesota. To avoid confusion the Iowa "Minnetonka" was abandoned.

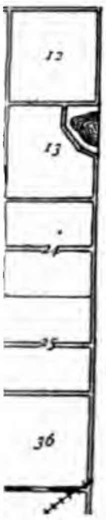
where the depth is at least 100 feet, but soundings of two or three times that depth are reported.*

The shores of Okoboji are for the most part high walls of bowlder-clay and drift; sandy beaches are less frequent. Everywhere the erosion of the waves has shaped the shores,

FIG. 20. Natural rip-rapping, shores of Okoboji.

undermining them and sorting their materials; the fine clays have been carried "out to sea," while the weighty bowlders are left behind every winter to be pushed up closer and closer by the ice, at length piled over one another in ramparts and walls, often riprapping the shore for long distances as if to simulate the work of civilized man. A beautiful illustration of this is seen along the southern shore of Lake East Okoboji, section 20. The less attentive observer would surely conclude that those stones were piled up by "art and man's

*The only authentic measurements we have at present were made by Mr. P. O. Myers, acting for the Botanical Laboratory of the State University. Mr. Myers found a depth of 185 feet at a point midway between Ft. Dodge Point and Miller's Bay.



BY

T.H.MACBRIDE
1900.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

device," a sea-wall to prevent further encroachments of the tide. At the southern end of Okoboji, near Gilley's Beach, is another fine display of bowlders, notable not so much perhaps for their position as for their variety and beauty. Here are bowlders of limestone, bowlders of granite of every sort, porphyry, syenite, trap, greenstone, quartzite, what you will, the debris of all northern ledges. Similar deposits are visible all around the lake, more especially on the eastern side, probably because the prevailing winds being westerly, the waves have exerted their more constant energy along the eastern bluffs.

East Okoboji lake extends from the most eastern point of Okoboji proper in an easterly direction for the distance of two or three miles, then bends to the north or northwest to meet the southern extremity of Spirit lake with which, without doubt, it was formerly connected. East Okoboji is nowhere very wide, perhaps a mile at the widest, generally not more than half a mile, but its length is considerable, nearly seven miles, or with its southern extension into Gar lakes, nearly ten. It reminds one of some noble river; it is like the Rhine with its frequent turns and narrows and the wooded slopes and hills that come on either side down to meet the water. It is a channel, the outlet of Minnewaukon and all its tributary lakes, marshes, ponds and pools, away in Minnesota, almost to the headwaters of the Des Moines. Yet is it not erosional; it is a valley of construction; it was here ere ever the currents that now on occasion pass this way began to flow. In fact the effect of current, such as there is, is quite the reverse of erosion; it is filling the channel, gradually leveling up from north to south this great depression. To the same end contribute all streams that come in from the shores, flushed sometimes with storm-water from the surrounding slopes. There are fortunately not many of these. But in days gone by the intermittent overflow of Minnewaukon delivered to the upper end of eastern Okoboji a large amount of sand, and the shallow waters are now rapidly filling up with vast quantities of aquatic vegetation.

These lakes taken all together form one of the attractions of Iowa. Their preservation in their pristine beauty is a matter of more than local interest. The waters themselves are not private property; they are under state control, and the state may very properly from time to time take action to prevent deterioration and destruction. The lakes in the vicinity of the town of Spirit Lake should be dredged, and measures taken to prevent the further entrance of erosive products. Steps also should be taken to control the level of water in the entire system as far as this is possible. The cost of such improvements as are here suggested would be small, insignificant, when compared with the good to be accomplished.

The Gar lakes extend from East Okoboji lake southward. They are three in number. An artifical channel connects the first (northernmost) of these with East Okoboji; a marsh connects it with Minnewashta, the next lake south, while the third in the series is joined to Minnewashta by a shallow channel through which, at moderate stages of water, the wind drives the waves and currents now in one direction now the other. The total length of the three lakes is about two miles, and they cover altogether an area of perhaps a square mile. Nevertheless they are not simple expansions of the drainage outlet of the larger lakes; they, too, occupy constructional valleys of depressions. Middle Gar or Minnewashta, has a reported depth of twenty feet, is a very pretty body of clear, pure water. The two others in the chain are much shallower and much afflicted with water weeds. Indeed if one may judge by present appearances, it seems likely that a ridge of drift once separated Minnewashta from Lower Gar, and that this has been removed as much by the beating of the waves, now on this side now on that, as by any other cause, as erosion. The more one investigates the problem, the more he will be disposed to the conclusion that the lakes, as a series, suffer diminution by evaporation chiefly; by overflow under exceptional conditions only, as of unusual rainfall, freshets and so forth, and even then the escape of the waters must be excep-

tionally slow, for the outlet seems to show practically no erosion. The thrust of the ice in winter,—ice two or three feet in thickness is said to be not unusual,—would, however, here as in the case of Spirit lake tend to rebuild the barrier between the lakes, even supposing erosion in spring or summer to have deepened somewhat the channel. It will be observed that the line of drainage, such as there is, lies through Spirit lake, East Okoboji and the Gar lakes. This is one reason, no doubt, for the great difference in depth shown when we compare the two principal lakes. Okoboji is out of the line of drainage entirely, always has been, and has almost no affluents. The two small streams that enter, one from the north, one from the south, bring with them at present almost no erosive material, the surface which they drain being yet grass-covered. Another cause for the difference between the great lakes in depth will be discussed in connection with the general topic, stratigraphy.

Center lake, lying chiefly in section 7, Center Lake township, deserves mention in this connection. It is a bright, sparkling sheet of water of considerable depth, evidently permanent. About one mile and a quarter long, and three-fourths of a mile wide, bordered on the east and southeast by a fringe of woods, it constitutes an attractive resort, though somewhat isolated and likely to be overlooked by the summer tourist. Center lake approaches to the southeast to within half a mile of Okoboji, and by a shallow marshy outlet is connected with the larger water.

The smaller lakes.—Besides the lakes in the central part of the county, the Minnewaukon and Okoboji system, Silver lake, Diamond lake and Swan lake, are topographic features likely to be permanent. The first named is a beautiful body of water, in the township of the same name, covering perhaps 1,000 acres, and has a reported depth of twenty feet. Diamond lake and Swan lake are much smaller and shallower. Stony lake, in Excelsior township, is a small body of water with marshy extensions surrounded by precipitous hills. The

water is reported fifteen feet deep. Pratt lake and Sylvan lake are larger but shallow, the latter a mere rush-covered marsh. Pillsbury lake, close by, is this year [1899] a beautiful sheet of water five or six feet deep, and a mile in length, but is reported inconstant. These three lakes have peculiar drainage to which reference will be made later on. Other small lakes in the county covering from eighty to 100 acres, some of them nameless and some of them not, are little more than persistent marshes for which thus far the agriculturist has found no convenient method of drainage.

DRAINAGE.

Dickinson and Osceola counties, though by no means lacking, as we have seen, in inequalities of surface, yet exhibit in very many places a remarkably incomplete drainage. The country in fact displays everywhere all the signs of newness, geologically speaking. Time, since the deposition of the later drift, has not sufficed to enable the streams or storm-waters to cut the necessary valleys back across the plateau or among the hills for the effective draining of the thousand minor depressions that everywhere mark the surface. Many of these perhaps never would be drained, at least by ordinary processes; such, for example, are the greater lakes we have just been studying; but there are hundreds and hundreds of minor pools and ponds that require time only when erosion effected by their natural overflow shall put their waters in connection with some neighboring stream and bring about at length their complete obliteration. The curious student may find examples everywhere. For instance, at the top of the hill in the Sw. ¼ of Sec. 20, Tp. 100 N., R. XXXVI W., near the highway is a pond which lacks but a little, one would think, to be entirely emptied down the hill, yet it may require some time before natural causes effect that thing. A similar pond lies near the top of the hill in the Sw. ¼ of Sec. 32, Tp. 100 N., R. XXXVII W. Here is a small lakelet fully seventy-five feet above the river valley, passing through the same section! Such a situation cannot in the nature of things be permanent,

and yet time enough has not elapsed since the formation of that pool for its obliteration. A more striking instance still, if such be sought, may be observed near the bridge in section 33 of Lakeville township. Here is a small lake sufficiently deep, not more than a rod or two remote from the banks of the Little Sioux, and yet even this has not been undermined and swept away by the erosion of that stream. *Tempus edax rerum;* the tooth of time it is that must elaborate the world and bring its rudeness to perfection.

Nevertheless Osceola and Dickinson are not without their creeks and rivers; the highlands are in the north and the general course of drainage to the south. However, the watershed of the northwestern part of Osceola county is to the west or southwest, and of the northeastern part of Dickinson to the north. The principal streams of the two counties may be enumerated from the west. The Little Rock river enters Osceola at the extreme northwest corner of the county, flows south less than a mile from the county line for three or four miles, then turns abruptly west, its waters drifting at length into the great Missouri. Otter creek next, takes origin in a marsh just west of Bigelow, Minn., near the state line, enters Viola township, passes Sibley on the west and south, and presently turning southwest emerges from Osceola county exactly at its southwest corner, only finally to contribute its waters to the Little Rock. East of Otter creek are one or two small streams which find their way southward and become tributaries of Floyd river, which also joins the Missouri near Sioux City. But the principal stream of Osceola is the far-famed Ocheyedan, a prairie river, narrow and rather winding in tortuous fashion through a constructional flood-plain, generally wide and far-expanded, sometimes narrowed to a gap between the hills. This in two branches crosses diagonally Osceola county entire. The principal stream takes origin in marshes just east of Bigelow, Minn., receives several minor tributaries from the east, one of which is the outlet of Rush lake, in Harrison township, is joined by its principal

western affluent, the Little Ocheyedan, and finally leaves the county about one and one-half miles west of the southeast corner of the county. The Ocheyedan drains the summit of the Altamont moraine which we have already described, what might, not without impropriety, perhaps be called the Ocheyedan moraine. For the most part an insignificant stream, near its mouth particularly it has effected considerable erosion. Judging from what we see to-day the valley of the river must have remained filled with ice until very late in the process of glacial retreat. Beds of gravel of aqueous deposition high above the flood-plain of the present stream, as in Sw. ¼ of section 17, Tp. 98 N., R. XXXIX, W., indicate that floods of water once passed entirely across and above the broad valley in which the prairie river now threads its course. We shall find occasion to refer to this again in speaking more particularly of the drift formations of this region. The amount of erosion effected by the stream since that earlier day when first it found itself draining a wide field of slowly disappearing ice has been, as would appear, comparatively small. Its destiny has from the first been well determined by a wall of pebbly drift, for the most part typical Wisconsin, completely hemmed in has it been by an insurmountable barricade, until reinforced by the waters of the upper Little Sioux, near the center of Clay county, it finally breaks the barrier and starts under the name of the latter river in the direction it has all along been seeking, off to the south and west.

The topography of Dickinson county is, as we have seen, much more irregular than that of Osceola, and the streams are proportionately more tortuous, especially in the western and central portion of the county. While the drainage as a whole is southwards, the water courses flow in almost any direction and present some very peculiar situations. The principal streams are Stony creek, the Little Sioux river with its tributaries, and Muddy creek. The first takes rise in Stony lake and derives its name from its bowlder-walled fountain. For the greater part of its course through the townships of Dickinson county, the stream is little better than a

marsh or quagmire. After it escapes the hills that immediately guard the lake to the south it simply forms a great slough extending diagonally across Westport township. The land on either side, however, is higher and the township otherwise pretty well drained.

The Little Sioux river is a much more considerable stream. Rising in the marshes of Jackson county, Minn., it enters Iowa by two branches, which, however, soon unite, and traverses Dickinson county in labyrinthine fashion from north to south, emerging near the center of the south line of Okoboji township. The east branch winds back and forth in the east tier of sections in Silver Lake township, receives as principal tributaries the outlet of Silver lake and Dug-out creek,—a stream whose very name indicates a popular appreciation of the rigor of our present physiographic problem—and finally meets the east fork in section 7, Lakeville township. Dug-out creek rises on the border of Osceola county not far southeast of the town of Harris. Its upper course is comparatively uneventful, but after leaving section 9 of Excelsior township it falls in with a tumultuous throng of precipitous morainic hills through which it appears to have literally dug its way. The creek amid the hills serves to bring into connection and so drain, very imperfectly, a series of marshes; otherwise its valley is very narrow and its waters with every freshet are still digging away at the stubborn ridges which still rise on all sides largely unaffected, everywhere to deflect the channel, now this way now that, to every point of the compass.

The east branch or fork of the Little Sioux is much the larger and may be esteemed the principal stream. It crosses with perennial waters Diamond Lake township, receiving on the way the overflow of Diamond lake, if such there chance to be. In this upper part of its course the stream is chiefly remarkable for the great disproportion which exists in many places between the size of the stream and that of the valley in which it lies. The valley is constructional; for instance in

sections 21, 29, 32 of Diamond Lake township. Where not constructional, especially after the union of the two branches, the valley of the river is narrow enough. Compare its course in sections 10, 15 and 16 of Okoboji township; indeed in all the northern part of this township. Here the river simply winds about among the hills checked on every hand by banks of Wisconsin drift, turning south through section 10 it makes a long detour of several miles only to return again to a point within less than half a mile of its southward moving waters before it finally emerges into the gravel plain and valley of the outlet of the greater lakes. In fact the topography of Okoboji township throughout is exceedingly complex and deserves much more consideration than it has here received. Near the middle of section 4, the river receives the outlet of Pillsbury lake; that is of the three lakes of the Pillsbury series. Platt lake, the most easterly of the three, extends east to within less than a hundred rods of the river. Nevertheless Platt lake drains northwest into Sylvan or Rush lake, this again south into Pillsbury lake, whence the drainage passes southeast for a mile or more among the hills, then turns north and northwest and enters the river through the channel of a little stream flowing from the southeast, which is again almost continuous with another drainage channel leading to the southeast.

After its union with Okoboji outlet the river traverses the Milford gravel-plain, through which it has carved a channel, until near the south line of the county, and in sections 33 and 34 it meets again a morainic ridge and is deflected westward and then southwestward, and so leaves our territory.

The outlet of the greater lakes, Okoboji outlet, follows as heretofore stated, a constructional valley among the hills until it strikes the Milford gravel in the northwest corner of section 7, Milford township, and possibly further, even to the middle of section 18. In the gravel the stream has already effected considerable erosion, notably east of Milford and in the vicinage of Okoboji Mills.

Muddy creek, the only remaining stream of any considerable size in Dickinson county, is for the greater part of its course a typical prairie slough. It rises in marshes in section 3 of Richland township and drains in most imperfect fashion this and Lloyd township farther south. After passing Terrill in the latter township, the stream occupies a broader and more definite valley, becomes a pleasant water course marked here and there by gravel terraces, after the manner of all south-moving streams in this part of Iowa.

STRATIGRAPHY.

FORMATIONS REPRESENTED.

The geological strata offered for study in Osceola and Dickinson counties are of the fewest. There are no traces whatever of the presumably underlying Mesozoic and Paleozoic formations. In fact all evidence goes to show that the drift in this part of Iowa is deep, hardly pierced even by the well-drillers who elsewhere always have some account to give of underlying rocky strata.

Mr. Meader, of Sibley, reports a well constructed by him south of Allendorf, in Osceola county, 515 feet deep, terminating in gravel. On the other hand there are reports [unverified] to the effect that some deep wells in the same county reached a definite sandstone. This perhaps indicates the Dakota sandstone, since that horizon is reported from Estherville at a depth there of 234 feet.*

The geological formations represented in the two counties now under consideration may be tabulated in accordance with present knowledge, as follows:

SYNOPTICAL TABLE OF GEOLOGICAL FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Glacial.	Wisconsin Gravel. Wisconsin Drift. Kansan.

*See volume VI of this series, p. 197.

GEOLOGICAL FORMATIONS.

GLACIAL SERIES.

Kansan Drift.—To the Kansan is here provisionally referred all the drift that is known to lie underneath the Wisconsin. This, so far as is known, is discoverable nowhere within the present limits by a natural exposure. But the testimony of well-diggers consistently affirms the existence beneath the superficial "gravel-dirt" of the vast beds of blue clay overlying beds of gravel. At Allendorf the blue clay is reported 250 feet thick. A few miles further south the blue clay is said to be 150 feet thick, while on about the same meridian near the county line the same stratum is described as 100 to 150 feet thick. In Dickinson county the presence of the blue clay beneath the ordinary drift is everywhere recognized and reported, but no data were secured as to its thickness; so far water seems obtainable upon its upper surface. Thus on Milford plain wells are sunk in the gravel to the blue clay with abundant water. In the western part of the county the blue clay is reached at a depth of no more than thirty feet. On the other hand, attempts to pierce the blue clay have been made in several places near the lakes with apparently small success. After going through the tough bowlder-thronged material for a distance of 150 to 250, or even 300 feet the operator seems, in all cases, to have abandoned the attempt and to have gone his way discouraged. But in any event, even with present data, we have every reason to believe that a comparatively thick sheet of blue clay, more or less charged with bowlders, underlies the superficial deposits of the whole of both counties. The thickness doubtless varies, but data are not yet forthcoming in number sufficient to enable us to say at present how or in what direction the variation occurs. But even with present imperfect knowledge of these hidden deposits we have hints of layers, stratification below the unoxidized clay. The well at Allendorf is 515 feet deep, and the record there, though not as accurate as could be wished, is yet very

suggestive. The surface drift is reported twenty feet deep; blue clay, about 250 feet; then sand and gravel; then yellow clay, about 200 feet; the gravel again, in which was found the sought-for water. There are other reports of similar import, but lacking details of measurement, so that it seems certain that one day the surface deposits of the region we study will be regarded as made up of at least three members, however these may ultimately be correlated with similar formations elsewhere in the state.

In the second place we describe in this connection, and so would refer to the Kansan drift-sheet, certain loess-like formations already mentioned in our study of the topography of the southwestern part of Osceola county. These deposits occupy a large part of Gilman township adjoining parts of Holman and Baker. The topographic features of the region have already been discussed. Their peculiarities, as contrasted with the topography of the adjacent country, have been accounted for on the supposition that the surface has been longer exposed to the wear and tear of time, of storm and flood. As to structure the characteristic Wisconsin is notably absent, though thin traces of it anon appear. The subsoil is everywhere, so far as observed, and likewise so far as reported, a stiff yellow clay with few bowlders or pebbles or absolutely none. In fact the country is loess-covered for a considerable depth; in some places, if the testimony of well-drillers may be taken, to the depth of twenty feet. Underneath again is the blue clay. It seems probable that we have here an uncovered portion of the original surface on which further north and east the Wisconsin was laid down. It is perhaps partly the oxidized and partly the loess-covered surface of the blue clay. We have here to do with a sort of limbus, a border-land, where owing to the very nature of the materials with which we deal, lines of accurate limitation are difficult to draw. Such lines may one day be drawn, but it will be after a most careful study of this whole area, section by section and field by field.

WISCONSIN DRIFT.

The Wisconsin deposits in Osceola and Dickinson counties present themselves under two distinct phases; the typical Wisconsin bowlder clay and a deposit of coarse sand and gravel, in places not few, superimposed upon the first. In general the Wisconsin clays, pale in color, surcharged in richest profusion with calcareous granules and pebbles, bearing abundant, often gigantic, unworn bowlders, cover the whole territory in question, with the notable exception of the limited portion of southwest Osceola county, to which reference above has just been made. The deposit is generally of indeterminate depth, so irregular is the topography; it is piled in the hills, buried in swamps, raised in long ridges, and again spread out in gentle declivities. Fine exposures are seen along the bank of Little Rock river, in the northwest corner of Osceola county, along the line of the B., C. R. & N. railway east of Allendorf, nor less at the bend of the Little Sioux river in Okoboji township, Dickinson county; and so almost everywhere where the surface soils have been removed in railroad building, or in the improvement of the common highway. Bowlders of every shape and sort are strewn in liberal profusion. These are commonly granite, but limestone is not wanting, and in some localities small, angular fragments of Sioux quartzite preponderate. These have been referred to as shown along the shores of Okoboji. In attempting to estimate the thickness of the deposit the best, in fact almost the only, data are those of the well.digger. In few instances, as in the railway cuttings west of Ocheyedan river, we may form some conclusions by comparing successive sections. Here the depth is fifty feet or more. The average for the county is probably much less. In the more level parts of Osceola the record of wells would indicate no more than fifteen or twenty feet as the thickness of the true Wisconsin, and even this surely diminishes rapidly to the southwest, though unevenly, until seen at length in scattered patches only, it vanishes entirely. Planed pebbles are not infrequent,

and in the better exposures small pieces of limestone with fine glacial marking may generally be collected. The morainic hills of both counties are generally piles of typical Wisconsin drift, though not infrequently gravel-capped and sometimes gravel throughout, at least as far as can be observed, as for example, the Ocheyedan mound and certain small hills near Diamond lake and elsewhere.

This leads us to consider the second phase of the Wisconsin deposits in our present field. The contrast between the two could not easily be more pronounced. The deposits we have been describing are typical glacial clays; their materials are indiscriminately mixed, heaped and tumbled, crushed and rolled together, big and little, coarse and fine, without any order. assortment or arrangement whatsoever. The terrace or gravel deposits, on the other hand, are all laid down with uniformity more or less pronounced, are all stratified, their materials assorted, arranged and re-arranged as by aqueous agency. The materials besides are all water-worn and their peculiar distribution, as we shall presently see, can lead to no conclusion other than that these deposits were laid down as the debris of former streams whose channels even yet may here and there be noticed, and measured by the islands and sand-bars they have left behind. These streams were glacial streams, they were coincident with the final retreat of what we have been calling the Wisconsin sheet when it had, in our region at least, been for many years reduced to no more than a series of gigantic glaciers lying in the constructional valleys of which mention has been made. As every one knows who has even watched the behavior of even the smallest streamlet, the finer materials are always swept away, deposited far down the stream, while sands and gravels are piled up in regular order wherever the valley widens or the current becomes in any locality for any reason less efficient. So the sands of Milford plain fill up a wide constructional valley, widest near Okoboji Mills and narrowing, as we have seen, at its exit from

the county. Into the preformed valley the sands from melting ice were swept, filling it from side to side to a depth of fifty, perhaps sixty feet, as one may see who stands on the hill-top south of the hills referred to, and looks across the valley of the Little Sioux and marks the long straight line of terrace on the western side; or he may note the benches further south in section 33 where the subsequent erosion of the river has left them bracket-like, high up on the sides of the bordering hills. Furthermore the streams that accumulated Milford sands seem to me to have been possibly, in part at least, super-glacial streams; they passed along on top of the ice. No streams in volume adequate to the effect could have passed down the valley of the "outlet" without showing more characteristic signs of erosion than now appear. But the deposits in question begin near the mouth of the outlet as if at the time of their deposition a glacier lay in all the valley occupied by the present lakes, extending even far down the outlet. Over this icy mass swept down the stream or streams that brought in part, at least, the debris that fills the Milford valley. It may be remembered in this connection that glacial ice, especially morainic or marginal ice, is seldom pure; it is often covered with morainic materials, filled with sand-bowlders and the gathered accumulations derived from the surface of its transit. It is difficult on any other theory to account for the distribution of the deposits which seem in other places to represent the formation now considered, for these gravels are by no means confined to Milford plain; they are scattered over our entire area, often, generally, far above the course of any present drainage system, entirely out of reach of any recent waters. Yet there they are all water-laid, stratified, cross-bedded even, in unmistakable fashion. For instance, on the top of the hill in the Nw. ¼ of the Ne. ¼ of Sec. 17, Tp. 100 N., R. XXXV, W., there is a gravel-pit which shows all these peculiarities, and there are many others across the northern part of Dickinson county, near Diamond lake, and indeed throughout the hill-country. In Osceola we have the

great Ocheyedan mound, not to speak of others, the upper part of which, 150 to 170 feet above the present stream, is made up of stratified sands and gravel. Across the Ocheyedan valley in the Sw. ¼ of the Se. ¼ of Sec. 17, Tp. 98 N., R. XXXIX, W., a cut in the highway shows the same phenomena. More

FIG. 21. A great pile of debris—the Sibley gravel-pit.

remarkable still is the great pile of such debris which forms the famous Sibley gravel-pit (Fig. 6). Here is a deposit twenty or thirty feet in thickness far away from any present water channel, but plainly of water-laid materials, resting unmistakably upon the uneven surface of the Wisconsin drift, for the contact has been in more than one place exposed. The only explanation of the gravel-pit is to be found in the carrying power of some broad drainage current flowing across the Allendorf moraine to find its outlet in the broader valley of Otter creek as it widens a mile or two southeast of Sibley.

Similar beds of gravel occur along the course of that stream, as in the Nw. ¼ of Sec. 29, Tp. 99 N., R. XLIX W., and so at Ashton, and ten or twelve miles further south where the gravel-pit of Sheldon exhibits the same characteristic features. The Ocheyedan mound, so far, at least, as affects the part of

it composed of gravel, must likewise have been heaped upon the ice or in the ice at a time when the Ocheyedan basin to the west was solid and full. Later on when the drainage began to follow the course of the Ocheyedan river, perhaps across the foot of the melting glacier, other correspondent or similar gravel terraces were laid down which may now be noticed along the banks of the present stream, twenty or more feet above the present flood-plain; as, for instance, immediately west of the mound on the west side of the river. The gravel in all the cases referred to, in fact in all cases observed, exhibits features of an ancient type, and one would be inclined at first to think it for this reason pre-Wisconsin. But there is no doubt of its horizon; it is post-Wisconsin. The material is doubless, some of it, from similar deposits of much greater age, and the rotten bowlders with which it is charged [see figure] may be thus accounted for; or we may apply the explanation suggested by Bain,* that the weathered bowlders are chiefly of the coarser micaceous granite, hence of the more quickly perishable sorts. In any case it is to the ordinary observer a matter of surprise to note how completely in hundreds of instances in the case of granite bowlders adhesion has broken down, so that through them the spade or shovel of the laborer goes as through compacted sand.

These gravel-deposits, as here described, ought to be reckoned as a distinct formation. As regards the true Wisconsin drift, they represent conditions entirely distinct and different. They stand to the Wisconsin, it would seem, precisely in the same relation as to the older Kansan stands the Buchanan gravels.

ECONOMIC PRODUCTS.

The economic products of this part of Iowa are not numerous. Its wealth is found in the exceptional natural fertility of its soils. Nevertheless we may here enumerate building-sand, gravel ballast, brick clay and native wood suitable for fuel.

*Vol. IX of this series; p. 96.

SOILS.

The soils of the counties before us are of two distinct types according with the stratigraphy above described. Thus in the Milford plain, and wherever gravel terraces have to any extent been formed, we have a light but warm sandy soil, fertile and usually productive save in seasons of prolonged drought. The advantages and disadvantages are those of sandy soils everywhere. The total extent of these soils, however, is comparatively small. Over the greater part of our area we have the rich black surface soil which characterizes nearly all the region of the Wisconsin drift in Iowa, a soil adapted to easy tillage, to the cultivation of every sort of staple crop. Underlain with a sub-soil peculiarly rich in lime, the region is especially advantageous for the production of wheat. The greater altitude, 1,000 feet above the prairies of the eastern part of Iowa, and the higher latitude, give in summer a much cooler climate, which contributes greatly to a generous harvest of the standard grain. The marshes and swamps, left incomplete by the peculiar conditions of their formation and rapidly yielding to the skill of the engineer, are everywhere subject to successful tile-drainage, and as is usual in such case will soon form part of the most fertile lands in the country. Even the steep hills of which these two counties have more than their share, afford pasture lands in quality unexcelled. There are practically no waste lands, and fine homes and barns and thriving towns afford on every side the most abundant and satisfactory evidence of successful agriculture.

SANDS AND GRAVELS.

The old river-terraces and outwashed gravel-plains and mounds furnish in all parts of the country supplies of sand suitable for the builder, while the gravel with which the sand is uniformly associated is useful in the construction of walks, of concrete for foundations, culverts, and in all places where artificial stone is to be manufactured. No ledges of rock are

exposed within these counties. Foundations are very commonly constructed of bowlders, which recent methods of handling render perfectly tractable and convenient.

The gravel also is of the utmost use in railway construction. Thousands of car-loads have been made use of by the two lines of railway having access to the gravel pit at Sibley. The gravel is likewise of that peculiar constitution which makes it of supreme value in the construction of roads and highways. Sibley, with the minimum of cost, may have the very finest of streets, and the whole region now under discussion needs no more than judicious management to have in time, with very limited outlay, a perfect system of rural highways.

BRICK CLAY.

So far as could be learned no brick is now manufactured in either county. The Wisconsin clays are not good for brick-making. But there is every reason to believe that good working beds of brick clay may yet be found in the southwest part of Osceola county where exposures of loess are not wanting. Investigation in the vicinity of Ashton, and especially toward the west and south, may be confidently expected to discover beds of loess thick enough for practical work. In the swales of small creeks occur sometimes beds of clay that appear promising. One such may be examined in section 6 of Goewey township, about one-half mile north of the Sharbandy schoolhouse. In any case it would seem the part of wisdom if those who construct wells or make excavations in the district named should be on the lookout for material in this county so much to be desired.

FUEL.

No coal is reported in these counties, nor is any likely to be encountered. The accumulated drift seems to be everywhere very deep, and there is no evidence that the usual coal-bearing strata extend so far north.* The only fuel supply now in sight for this part of Iowa is found in the groves of

*There is an unverified report that coal has been discovered near Estherville.

timber, either native or planted. In Osceola county at the time of its settlement native trees were exceedingly few; over the greater part of the county not one. However, there seems to have been a limited number of forest trees about the south end of Iowa lake, Fairview township, and in the center of Grove-island lake there appears to have been a considerable growth of Ash and possibly of other species. The lake named was a wide marsh, now drained, but the grove is still extant. Dickinson county was much better supplied. Fine stretches of forest stood about the larger lakes, especially in Center Grove township. Trees of considerable size furnished the early occupants of the county with not only abundant fuel but with lumber, and so made house-building possible at a time when it had been difficult, if not impossible, to obtain building materials from localities remote. The original forest trees in every locality are largely gone, but extensive areas of second-growth still furnish a source of fuel supply very convenient to a large number of people. But native resources of this sort have long since ceased to be the principal recourse. Planted groves dot the universal prairie, and every farmer finds on his own land a timber and fuel supply of greater or less value, according to the extent and variety of his planting. A list of the forest trees now growing in the district is appended further on.

WATER SUPPLY.

The water supply of this part of the state is chiefly in wells. Not that there is lack of streams, but these, as has been seen, are not large or numerous. Little Rock river is a fine stream, in the extreme northwest of Osceola, and the Ocheyedan and Little Sioux are convenient and unfailing. The abundant lakes in Dickinson county are of inestimable practical importance. But wells are everywhere in use even for watering cattle, and have been found so far very easy of construction. In few places have deep wells been found necessary.

The streams of the region are little used for purposes of water power. Such use has been attempted in several places,

notably at the outlet of Spirit lake, at Milford [the old town], at Okoboji Mills, but none of these efforts are now in successful operation. The constant volume of water is perhaps nowhere sufficient to afford for such enterprises any great promise for experiment for the future. In natural beauty and attractiveness Osceola and Dickinson counties are second to no other region of the state. But in economic resources they must depend chiefly upon the exuberant wealth of a marvelously fertile and productive soil.

ACKNOWLEDGMENTS.

In preparation of this report the author has enjoyed the advice and assistance of many of the citizens of each county. Hon. R. A. Smith, of Okoboji, was able to furnish the greatest assistance, having been previously associated with Doctor White in a similar enterprise. The writer would also record his sense of obligation to Mr. O. B. Harding, of Osceola county; Mr. G. B. Meader, of Sibley; Mr. Otto Turk and Mr. J. P. Hawxhurst, of the same city; Mr. A. A. Henderson, of Okoboji; Mr. H. F. White and Mr. J. M. Brown kindly furnished records of elevations for points along the line of the B., C. R. & N. railway; Mr. D. J. Whittemore did the same for the line of the C., M. & St. Paul railway, and Mr. C. W. Johnston for that of C., St. P., Minn. & Omaha road. Professor Calvin and Mr. Bain of the Survey have been of constant assistance throughout the work.

FORESTRY NOTES FOR DICKINSON AND OSCEOLA COUNTIES.

Of the conditions by which forest distribution in Iowa was originally limited no better illustrations could be found than those afforded by the situation presented in the two counties of Osceola and Dickinson. Osceola was practically treeless, because fire-swept; the only native grove, as above noted, occupied an island in the middle of a lake! A similar tree colony stood in an exactly similar situation in the midst of a marsh a few miles east in Dickinson county. The number of

species on these islands is not great. Soft Maple, White Ash, Wild Cherry and Plum are the principal forms now occurring on the islands. Doubtless in the marshes here and there stood a Willow and by the streams perchance a Cottonwood, but aside from such isolated specimens there were no trees in Osceola county.

FIG. 23. *Quercus macrocarpa* Mx. Bur Oak. A few of the primeval trees of large size are still standing.

Dickinson county was much better supplied. In the neighborhood of the great lakes were considerable areas supporting, in some localities at least, a heavy forest. Thus the whole area now platted as Arnold's Park was originally woodland, with trees of large size, furnishing most valuable lumber

to the early pioneer. This region is still largely wooded, although the primeval Oaks and Walnuts have mostly disappeared; and there is a continuous fringe of woods along the entire eastern shore of Okoboji, which is doubtless primeval. There was another fine grove east and south of Center lake, the descendants of which still exist in the same territory, with here and there a primeval Elm or Oak. One of the latter has been thought worthy of illustration here. Again, there was a very large tract of woodland east of East Okoboji lake, and this was continuous with a fringe of trees that encircled Spirit lake more or less continuously all around. The woods about Spirit lake were wanting chiefly toward the northeast and north, and were more abundant to the northwest among the lakes and ponds abounding in that quarter. There were also fine groves of native timber in the vicinity of Pratt lake and along the steep sides of the valley of the Little Sioux, more particularly in the center of Okoboji township. At present groves and thickets of second growth in all these places occupy nearly all the earlier forest territory and have probably in later years somewhat extended the original forest limit. The cutting out of the larger mature trees has given opportunity for the oncoming of hundreds of younger ones, and the suppression of autumnal fires has given a chance to every seedling, so that at present the actual number of trees in the region of primeval woodland is probably greater than ever before. Small numbers of native trees were also found on the eastern or southeastern shores of Diamond lake and Silver lake, and in other places not here named perhaps a few. The scarcity of trees in this part of Iowa has in some cases led to the preservation of the woods. Besides, here as elsewhere in Iowa, trees generally occupy the less fertile and less desirable land, stretches of sand, steep clay hillsides, deep ravines, in short localities which give in their perpetual harvest of wood and fuel the best return of which the soil is capable. Most of the farmers owning such lands appreciate this. In many places, however, the desire to convert such

lands into pasturefields is making for the destruction of the woods. In some places, even along the lakes, where their esthetic value, if nothing else, would seem to demand their preservation, the forests are being extirpated by the axe, in others by over-pasture; especially have the woodlands suffered during these later years of unusual drought. There are many places where trees of various sorts and kinds have perished simply from drought. This fact should lead the owners of wood-lots to treat them hereafter with greater consideration, if the native groves are to survive at all. The amount of grazing should be limited, and restricted to the winter months if permitted at all. A list of trees native to the region and which may, therefore, be cultivated in this climate with some expectation of success is appended.

But for the forestry of our region, an account which would deal with the native groves alone would be incomplete indeed. What was once rightly called treeless Osceola appears to-day as a wooded country from which the farms have possibly been shaped by clearing, so abundant in various places are the groves, so extensive the arboreal plantations. Tree claims in this part of Iowa make a better showing than almost anywhere else. The accompanying illustrations show how completely a prairie landscape may, in twenty or thirty years, be transformed. Piesle's grove in Viola township, northwest of Sibley, is a fine example. The species commonly planted are Cottonwood, Willow and White Ash. The Soft Maple and Box Elder also find place. In many of these groves several other native species are beginning to appear, seeds having been probably dropped by birds. The Wild Grape, Virginia Creeper, Wild Plum, Wild Cherry are among these. In fact it is perfectly evident, proved by experiment, that the prairie farmer may have the advantages of a contiguous wood-lot, in northwestern Iowa, just to the extent desired. Without the planted groves the northwest prairie, storm-swept in winter, sun-scorched in summer, had been almost uninhabitable; with the

groves the severities of climate are so reduced as to make these farms among the most attractive.

The species cited, used in plantations, have the advantage of very rapid growth, and to this extent have served an immediate excellent purpose. The only form of lasting value is the Ash. This tree has all valuable qualities. It is an excellent shade-tree, it makes the best of fuel, and its wood is serviceable for all sorts of purposes on the farm. It should be more widely planted. It is time the Cottonwoods, Box Elders, etc. were gradually supplanted by trees of more valuable, more enduring, species. The accompanying catalogue of native trees furnishes a list from which selections may be made. The Elms, the Bur Oak, the Red Oak, the Hackberry, the Red Cedar or Juniper, the Linden or Basswood, are all indigenous species and certain to thrive if properly protected and cared for. Those farmers who have been so preeminently successful with the less desirable Cottonwoods have already established more or less perfect forest conditions into which the successful introduction of the more desirable hardy trees will be a matter of proportionately small difficulty. With the trees named should be introduced as border trees the Hazels, Crab-apples, Plums and Haws. These fill in the space unoccupied by the branches of the larger trees, say the lower fifteen or twenty feet, and make an excellent thicket and wind-break. Such trees border the forest in nature and we may hope to use them with greatest success and profit. The Juniper is the only native conifer, evergreen. Probably some other introduced species may give greater satisfaction. The White Pine and the Spruce promise well. And perhaps the western pine, *P. ponderosa*, may be found useful, as its eastern range was certainly in the more recent past not far west of the Missouri and Sioux valleys.

It would be interesting to enquire how these natural groves attained their present station. Are they the remnant of a forest once continuous from the Rocky mountains to the Atlantic coast, burned out by drought and fires and so reduced

to this sad residue? or are these groves an extension of the forests from the east, the seeds brought hither by the winds and birds? Here is a question difficult to answer; the data obtainable not yet, perhaps, all in. Many species found around the lakes are such as to favor the latter supposition; the seeds might easily, by birds or winds, be scattered wide; but there are other species which look quite as decisively in the opposite direction. Walnuts and acorns are not by any animal save man likely to enjoy the transportation needed. The far eastern extension of some western species of trees as *Pinus ponderosa* at Long Pine, Neb., for instance, would seem also to look in the same direction. Prior to the advent of civilized man the forests of the continent were probably already through natural causes slowly retreating; our occupancy of the land may have only hastened nature's purpose. Here at least is a problem for our study. Hereafter, if we are to have trees and forests, we may count on having to toil for them. Eden's gate is angel-guarded.

A NATURAL PARK.

The chain of lakes we have attempted to describe, together with the groves of native oaks and elms about them, make up a natural park, taken all in all the finest in the state. There is so much native beauty as to render almost impertinent, needless, any art or artifice of man. Minnewaukon, Okoboji, had remained forever glorious. But civilized man would use the fair fields of the natural world. He throngs in thousands about each scene of natural splendor and it forthwith becomes necessary to make appointments which shall at once meet his convenience and check his vandalism. As the years go by the lakes are destined more and more to serve our Iowa people as a delightful, a convenient summer resort; to the fortunate a summer home, to toilers in shop and field a resting place where, for at least a day or two, each may forget his usual care and burden.

For this reason it seems that these groves and lakes should receive at the hands of legislators the very best attention they

can give. The waters are already the property of the state; the shores should be as well, at least so far as is necessary to preserve intact, from injury or abuse, those portions not likely to be used by homes and villas. The scant woods by nature placed to decorate these winding, bowlder-covered banks should be religiously preserved. This will be possible only by public ownership of some intelligent sort. The state of Iowa should own these lands and provide for their proper control and management. The entire circuit of the lakes should be a highway, unimpeded, open to the world. No fences should, anywhere, come down to the water's edge, much less as now invade the lakes; nor should any obstruction or unsightly thing whatever be permitted to trespass upon a territory devoted to the instruction and peaceful enjoyment of an intelligent, orderly, happy people. Surely the time has come when our people may own and control a park by nature so fine as this, and by controlling it preserve it to the comfort and enjoyment of those who, in time, shall follow us. Naturalists will find here exceptional advantages for the prosecution of their work, and summer schools of science might flourish here as in no other quarter of the state. Let the people, not of Dickinson county only but of the northwest, once appreciate what these lakes are actually worth, and their preservation and control will no longer be a matter for argument or doubt. The lakes of Dickinson county are the opportunity of the state.

WOODY PLANTS OF DICKINSON COUNTY.

The following is a list of the woody plants of Dickinson county. In its preparation the author acknowledges the assistance of Hon. R. A. Smith, a life-long observer of the natural conditions about the lakes:

Tilia americana Linn. Linden, Bass-wood, Linn. Not uncommon between Lake Okoboji and the Gar lakes; also found along the Little Sioux river in Okoboji township. A valuable tree well worthy of cultivation; beautiful for shade and useful for lumber.

Xanthoxylum americanum Mill. Prickly Ash. Found occasionally around the lakes and along the Little Sioux. Valuable as an ornamental shrub only.

Acer saccharinum Wang. Hard maple, Sugar Maple. Occurs sparingly about Lake Okoboji. A tree of the highest value, but less likely to flourish in cultivation in this section of Iowa. Trees raised from the seed in groves are most promising. Nowadays called *Acer saccharum* Marsh by some authors.

Acer dasycarpum Ehrh. Soft maple, White Maple. Probably native. With such trees as this and the Cottonwood it is difficult to say whether they are indigenous or not. The two species are everywhere planted, and it is possible in the case of the Soft maple at least, that trees now supposed to be native are really descended from those planted by white men. A tree of the highest value in plantations, affording shelter, shade and fuel. It should, however, now be supplanted by species of more slow-growing hard-wood trees. By some authors written *Acer saccharinum* Linn.

Negundo aceroides Moench. Box-elder. Very common in cultivation. Probably native also about the lakes and the Little Sioux. The species also comes rapidly from the seed, but its chief value is as a nurse for other more slowly growing trees. *Acer negundo* Linn is the name preferred by some authors.

Rhus glabra Linn. Sumac, Smooth Sumac. Not abundant. Here and there on wooded hillsides along the lakes and the Sioux. Useful only as an ornamental shrub.

Prunus americana Willd. Wild Plum. Not uncommon about the lakes and by the banks of the Little Sioux. Valuable for fruit, valuable also as an ornamental tree and as an element of the thicket wind-break.

Prunus virginiana Linn. Choke-cherry. Apparently rare. The only specimens observed were along the Little Sioux. Probably occurs also about the lakes, Useful only as a thicket-tree, where its early clusters of white flowers, later shining black berries, make it very attractive.

Prunus serotina Ehrh. Wild Cherry. Mr. Shimek reports this as occurring about the lakes, and small trees are found on the island in Grove Island marsh. A most valuable and beautiful species.

Pyrus coronaria Linn. Crab-apple. American crab. Not rare around the lakes. Tends to form a thicket, and is invaluable for this purpose, as forming an elegant and serviceable border to our forest plantations. The tree is besides one of our most beautiful ornamental trees.

Crataegus coccinea Linn. Hawthorn. Red Haw. Occurs sparingly along the Little Sioux. Mr. Shimek reports this also from the vicinity of the lakes. Very handsome, useful as an ornamental tree.

Cornus stolonifera Michx. Red Osier. Dog-wood. This handsome little shrub occurs not infrequently along the eastern shores of the Gar lakes. Probably not uncommon throughout the native groves. Flourishes in wet regions especially north and does not well bear transplanting.

Cornus paniculata L'Her. Panicled Cornel-bush. Rather rare along the lake shores. This is the most attractive of our native species, but does not flourish well on our dry uplands. The cymes of white flowers are very pretty and in fall the snow-white fruit distinguishes it.

Sambucus canadensis Linn. Elder-berry. Not common. Apparently native along the Little Sioux. Reported indigenous by the lakes, and found here and there in cultivation in gardens.

Viburnum lentago Linn. Black Haw. There are two species popularly called Black Haw, and the two forms are not always readily distinguished. The species named here is a small tree fifteen or twenty feet high, slender, with few branches; common in Minnesota and north and east. It occurs rarely in the valley of the Des Moines ten or fifteen miles east of the lakes.

Fraxinus americanus Linn. White Ash. Common everywhere, especially about Spirit lake, Hottes lake, along the Little Sioux, and everywhere planted. The species grows

somewhat slowly as compared with cottonwood, but is two-fold more valuable and makes a much handsomer grove and better wind-break. It is a matter of some surprise to find this species so common and hardy here. It is *par excellence* a forest tree, and shows its most perfect development in typical forest conditions much farther east. It would never be classed with the bur oak, which here it seems to rival. The fact that it is so hardy here indicates that it is just the tree for planting on these northern prairies, as the farmers fortunately need not be told. All the trees of this part of the world are more shrubby and bushy than farther east; probably because of the much harder conditions they have been called to face, especially in the matter of fire.

Ulmus americana Linn. Elm, White Elm, American Elm. Common. A most valuable tree; tough, hardy and beautiful, deserving a place in every plantation and by every roadside. Easily transplanted and easily cultivated.

Ulmus racemosa Thomas. Cork Elm, Hickory Elm. This species seems to be uncommon throughout our region. It is rather smaller and more bushy than the preceding, but the wood is finer grained, tougher and for many purposes more desirable. It may even take the place of hickory in the manufacture of tools and agricultural implements. It is, therefore, in the highest degree worthy of cultivation and preservation.

Celtis occidentalis Linn. Hackberry. Not uncommon. Said to have been in other days a very prominent forest tree, now represented by small specimens only. A fine ornamental tree, growing rapidly on prairie soils, but the wood is valuable chiefly for fuel.

Juglans nigra Linn. Black Walnut. Mr. Smith reports that black walnut trees of great size were once here at the service of the pioneer. Occasional trees are still to be seen. This is one of the most valuable of North American forest trees; easily cultivated, and the people of these counties may congratulate themselves that such a tree is here indigenous. From the seed in prairie soils it grows with great rapidity,

but needs the protection of trees of other species. Walnuts are not easily transplanted, nor do they thrive if set singly or even in rows, that is, in one long line. The walnut is essentially a forest tree and must be bordered at least with trees of other species.

Carya amara Nutt. Bitter-nut, Pig-nut, White Hickory. Not very common. Small trees occur here and there in the lake woods, and some trees were noticed on the banks of the Little Sioux. A tree of comparatively small value, except for fuel. Like others of its family, it does not endure transplanting, but must be cultivated from the seed. The shell-bark, or white hickory proper, is not reported from these woods.

Corylus americana Walt. Hazel, Hazel-nut. Not rare along the borders of the woods and thickets; also along the Little Sioux. This species also must be cultivated from the seed.

Ostrya virginica Willd. Iron-wood, Hop-hornbeam, Leverwood. A small tree, furnishing very hard and strong wood, useful for tool handles, etc. Occurs not infrequently along the lakes and by the Little Sioux.

Quercus macrocarpa Michx. Bur Oak. Very common. By far the most common species of tree in this section of country. A few of the primeval trees of large size are still standing, near Center Lake, and on the hill enclosed by the great bend of the Little Sioux in Okoboji township. The species shows a small-fruited variety; acorns less than half an inch in diameter are the rule. This species is exceptionally hardy; groves of it occupy sometimes lonely exposed positions, where scattering small trees six to ten feet high seem to persist unchanged, growing only in slowest fashion year after year. The wood is for some purposes exceedingly valuable and good but in general is less desirable than that of the white oak which does not here occur.

Quercus rubra. Red Oak. This is the only black oak of this region; not uncommon. Trees of large size were once abundant about the southeast side of Okoboji. A very valuable lumber-tree. It is, however, like the walnut, a forest

tree, and may be expected to grow to perfection only in a forest plantation, affording forest conditions of moisture and shade.

Salix longifolia Muhl. Long-leaved willow. Very common everywhere in the wooded district, especially around Spirit lake.

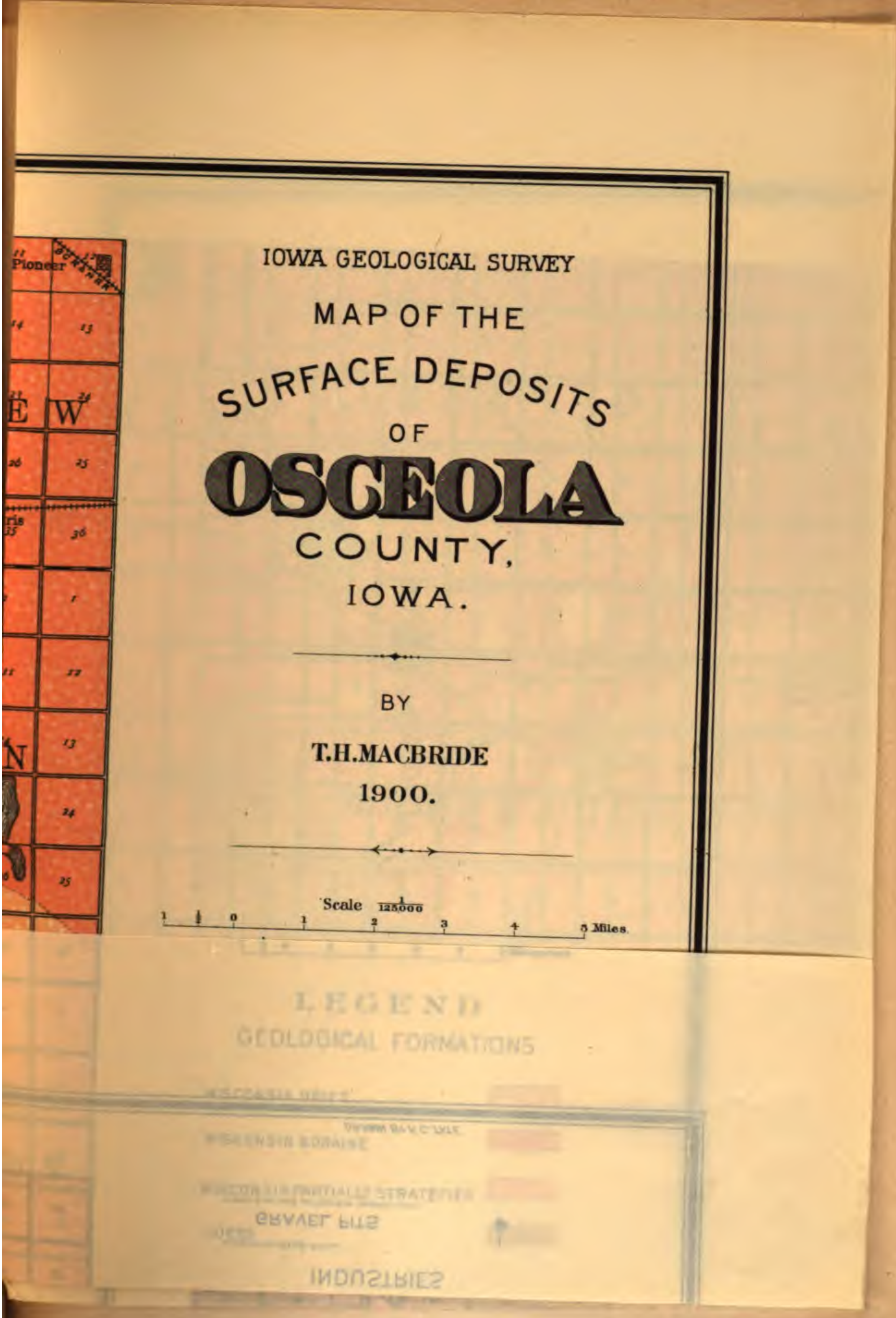
Salix amygdaloides Anders. A bushy shrub or small tree, easily distinguished by its rather large leaves, two to four inches long, white, silky beneath. Of little value save as an ornamental shrub.

Salix discolor Muhl. A small tree fifteen to thirty feet high, not rare about the marshes and lakes of Dickinson county.

Populus tremuloides Michx. Quaking asp. American aspen. Not uncommon through all the groves, especially in low grounds. The wood makes light fuel; otherwise the tree is of small value save as ornament.

Populus monilifera Aiton. Cottonwood. This tree is so commonly planted that it is by some doubted whether it be even native of either county. It seems probable, however, that the cottonwood is one of the trees indigenous to both counties. The seeds are particularly well adapted to dispersal by the wind, and young cottonwoods are almost always to be found far out on the prairies and plains. That it were not native to the two counties would be remarkable indeed. Useful chiefly because of its rapid growth; but for this very reason of the highest utility and service.

Juniperus virginiana Linn. Red Cedar. Juniper. This is the only conifer, evergreen, native to the region. A few fine old trees are yet standing near Lake Okoboji on the eastern shore. One near Fort Dodge Point is extremely old; a foot or more in thickness. This tree grows rapidly in cultivation, is remarkably handsome in its youth, but is apt to be damaged by snow as it grows older, and so loses its symmetry. It endures shade much better than most evergreens, and makes fairly good ornamental hedges and wind-breaks.


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
OSCEOLA
COUNTY,
IOWA.
BY
T.H.MACBRIDE
1900.
Scale 1/125000
1 ½ 0 1 2 3 4 5 Miles.
Pioneer

GEOLOGY OF HARDIN COUNTY.

BY

SAMUEL WALKER BEYER.

GEOLOGY OF HARDIN COUNTY.

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INTRODUCTION.

LOCATION AND AREA.

Hardin county is located in the north central portion of the state. It is the fifth county from the north and east borders, sixth from the south and seventh from the west border of the state. Franklin county bounds it on the north, Story and Marshall on the south; while Grundy and Hamilton counties form its east and west boundaries respectively. The second correction line crosses the county and breaks its rectangular symmetry by causing a shift of the northern tier of townships nearly two miles to the westward The county is composed of approximately 516 square miles divided into fifteen townships. The three southern tiers are standard congressional townships save Jackson which takes one-half square mile from Ætna. Alden and Hardin of the north tier divide equally three of the regular townships.

Geologically the county is of especial interest because it is one of the border counties of the productive coal measures, and its surface has been modified by at least three ice invasions. It is instructive physiographically on account of its varied surface. It presents three topographic types; true erosional in the southeast, semi-erosional in the northeast and typical glacial undrained in the western and by far the greater portion of the county. It merits attention economically because of its stone and lime of the Lower Carboniferous, coal measure shales; and above all on account of its agricultural wealth, due to its well watered surface and fertile soils of the Pleistocene.

HISTORICAL RESUME.

Hardin county was one of the most inviting of the interior counties to the pioneer settler. This was due in large part to the broad timber belt which flanked the north branch of the Iowa river. Thriving settlements early appeared in the "Big Woods" and Steamboat Rock, Hardin City and Alden flourished long before the railroad invaded the territory.

Geologically the county received early attention. Although not mentioned in detail it was included in the area represented on Nicollet's map of 1841.

David Dale Owen* in exploring the "Iowa Coal Basin" ascended the Iowa river to Alden in 1849, and in his classic report gives a general description of the rocks which constitute the Iowa river section. His is the first specific mention of the geology of the region and he was the first definitely to refer the beds to the Carboniferous.

A. H. Worthen,† under the direction of James Hall, visited Iowa Falls and traversed the Iowa river from Eldora to Steamboat Rock. He briefly describes the Iowa Falls section and discusses the assemblage of rocks near Eldora in some detail. Worthen notes in particular the distribution of the coal and the structural peculiarities of the region.

White,‡ a score of years later, under the title of county geology, gives a brief statement concerning the Eldora coal basin which is much more general than either Owen's or Worthen's.

McGee,§ in his Pleistocene History of Northeastern Iowa, casually mentions the Kinderhook beds at Iowa Falls and the gorge of the Iowa river between Iowa Falls and Eldora.

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*Report of a Geological Survey of Wisconsin, Iowa and Minnesota, pp. 103-104. Philadelphia. 1852.

†Hall, Geology of Iowa, Vol. I, Pt. 1, pp. 181-182 and 266-272. Des Moines, 1852.

‡White, Geology of Iowa, Vol. II, pp. 257-258. Des Moines, 1870.

§11th Ann. Rept., U. S. G. S., Washington, 1889-1890.

PHYSIOGRAPHY.

TOPOGRAPHY.

Hardin county breaks up into three well-marked topographic provinces coincident with the three drift sheets which are in large measure responsible for the surface features of the county.

The first may be designated the loess-Kansan type and comprises about one-sixth of the superficial area of the county. In this province are included the east half of Providence, all of Union, all save the western tier of sections in Eldora, and the southeastern third of Clay township. The surface is characterized by being perfectly drained, and the salient features are in complete harmony with the drainage lines. In fact they are the results of stream dissection, and hence the fitness of the name erosional topography, of which this area may be considered typical. The large streams flow through well developed valleys and have deposited some alluvium, while their secondary and tertiary tributaries have reached a less advanced stage of development, yet have cut well headwards until the divides are thoroughly drained. In their middle courses these streams flow through sharp gorges. Of this style of stream the north fork of the Iowa may be taken as a type, and this, with its immediate tributaries, is responsible for the most rugged topographic features in the county.

The maximum surface inequalities in this province exceed 150 feet and the upland salients approximate 100 feet above the minor drainage lines. The surface features in the province are believed to be the oldest of any in the county and are graven largely in the later deposits of drift and loess. Away from the stream the elongated hill of the "paha-type" of McGee so characteristic of the marginal portions of the Iowan drift, may be viewed along the south half of the Grundy-Hardin county line. These eminences trend northwest-southeast.

The second topographic province is the Iowan drift plain and comprises the east half of Ætna and the northeast third of Clay township. This is a portion of the great Iowan drift plain which extends from the Minnesota line across Worth, Cerro Gordo, Franklin and the northeast corner of Hardin to Johnson county and forms a broad plain of several thousand square miles area. It is characterized by extreme surface monotony, the streams having done comparatively little cutting. They have low gradients and the reliefs are much more subdued than those of the loess-Kansan. The surface is moderately well drained and the topographic features are in general accord with the drainage lines. Upland surface irregularities scarcely exceed twenty to forty feet in Ætna township.

The third topographic province comprises the area covered by the Wisconsin drift sheet and constitutes more than four-fifths of the area of the county. Its eastern margin is marked by a sinuous chain of hills and knobs, which together form a broad but varying ridge which rises from thirty to sixty feet above the adjoining upland and is known as the Altamont moraine. The morainal tract varies from two to five miles in width, enters the county west of the middle line of Ætna township, extends east of the Iowa Central at Abbott crossing, turns westward of Abbott, then south, crossing the Iowa river above Steamboat Rock, forms the ridge north of Eldora and Eldora hill upon which the town is built, continues southward and then southwestward, crossing the south fork of the Iowa river just east of the Pleasant-Eldora township line, and looping strongly to the westward forms New Providence hill, whence it turns to the south entering Marshall county. Excluding the morainal belt the third topographic province may be designated the Wisconsin drift plain. Its general surface departs but slightly from a plane. It is characterized by great numbers of saucer-like depressions and knob-like eminences. There is a great scarcity of drainage lines and broad areas are almost wholly undrained. The principal streams have cut deep trenches and often flow between abrupt

walls, and still retain high gradients, showing that their work of down-cutting is not yet completed. In fact the general surface features are those of topographic immaturity.

As in Story so in Hardin county, certain concentric chains of ridges may be observed more or less paralleling the outer moraine. As a rule these recessional moraines lack continuity and cannot be traced any great distance. One such ridge may be noted. It crosses Tipton township from southwest to northeast, cuts the southeast corner of Ellis and northwest corner of Jackson, and continues into Hardin township. This moraine is largely responsible for the complicated bends in Tipton creek and south and north forks of the Iowa river.

Tipton, southern Ellis and Pleasant townships, although they lie wholly within the Wisconsin province, are deeply trenched by the South Fork, Tipton creek and their tributaries, and show some of the most vigorous reliefs in the county. The morainal crossings of these streams are marked by bowlder barriers which form rapids.

The Altamont moraine forms a more or less broken ridge extending entirely across the county with crests reaching an altitude of more than 1,100 feet above tide. West of Ackley the ridge has an elevation of more than 1,200 feet; the highest points in Ætna, Jackson and Clay townships where the moraine crosses the river, above 1,150 feet; Court House hill in Eldora 1,110; and New Providence hill 1,130 feet. The highest point in the county is believed to be the crest of a morainal hill north of the Iowa river between Iowa Falls and Alden, which has an altitude of about 1,225 feet. The lowest point is where the Iowa river crosses the Marshall county line at an elevation of 910 feet, giving a maximum surface relief of 315 feet.

The following table of elevations alphabetically arranged is appended:

Table of Elevations.

STATION.	Feet above tide.	AUTHORITY.
Abbott	1099	B., C. R. & N.
Abbott	1091	Iowa Central.
Ackley	1092	Iowa Central.
Ackley	1101	Illinois Central.
Ackley Crossing	1095	Iowa Central.
Alden	1170	Illinois Central.
Clives	1070	B., C. R. & N.
Eldora	1068	Iowa Central.
Eldora Court House	1110	Barometer.
Mill at Eldora, low water level below dam	955	Barometer.
Gifford	945	Iowa Central.
Gifford	948	C. & N. W.
Hubbard	1094	C. & N. W.
Hughes	1120	Barometer.
Iowa Falls	1107	B , C. R. & N.
Iowa Falls	1108	Illinois Cent. crossing.
Moraine west of Ackley	1200	Illinois Central.
New Providence	1130	Barometer.
Owasa	1110	Barometer.
Robertson	1175	B., C. R. & N.
Radcliffe	1189	C. & N. W.
Steamboat Rock	976	Iowa Central.
Union	928	Iowa Central.
Whitten	1036	C. & N. W.

DRAINAGE.

As implied in the discussion of topography the development of drainage lines bears a close relationship to topographic development. So close is the relationship that it is impossible to give a complete exposition of the one without a thorough understanding of the other. The amount of work the streams of a given area may do depend largely upon the "run off," *i. e.*, the amount of water which actually runs off of the surface. The run-off, barring factors of minor importance, is a function of the rainfall and topography. In an area with a vigorous surface relief, the percentage of run-off to rainfall is high, while when the features are more subdued the percentage is correspondingly less. The mean annual rainfall for the county is about thirty inches, and it is believed that about thirty per cent of this is carried away by the principal streams and is, therefore, efficient in sculpturing the land.

In the loess-Kansan province water courses are well developed, the divides are thoroughly dissected by the numerous small tributaries and the surface is completely drained. In the Wisconsin topographic province the drainage systems are barely outlined. Branchless streams when traced headwards lose themselves in a maze of more or less disconnected chains of prairie swales and sloughs. Ponds and kettle-holes are everywhere the rule, often overlooking the best developed drainage lines in the region. Formerly water persisted in many of these basin-like depressions throughout the year, and muskrat houses were familiar features of the landscape. At present tile-drainage and cultivation has rendered these natural basins transient receptacles for the excess of rainfall, although a few still persist even during the driest seasons.

With the exception of inconsiderable areas in the southwest and northeast corners of the county drained by tributaries of the Skunk and the Cedar river systems respectively, the Iowa river with its tributaries drains the entire county. The Iowa river system, as is true of the majority of the river systems of the state, is asymmetric, with the greater number of important branches joining it from the south and west. The system comprises the Iowa, proper; with South Fork, Honey, Mud and Minerva creeks from the west; Elk, School, Pine and Bear creeks constitute the more important tributaries from the north and east.

Iowa river.—The Iowa has its source in the lakes and ponds of Hancock county, enters Hardin county near the middle line of Alden township and takes a most sinuous southeasterly course across the county, entering Marshall about two miles west of the east line of Hardin county. Below its junction with South Fork, the Iowa flows through a broad terraced valley, varying from three-fourths to one and a half miles in width, and has a flood plain averaging a half mile in width. The gravel terrace measures twenty feet above the flood plain at Gifford, ten feet at Union, and is scarcely recognizable

beyond the Marshall county line. The Iowa Central is built on this terrace.

The stream meanders greatly over this broad alluvial flat. Indurated rocks appear in place in the stream channel below the mill at Union, and support the flood plain, rising above

FIG. 23. Iowa river valley between Xenia and Eldora, looking north. Here the river flows through a narrow valley and has deposited little alluvium.

low water level, between Union and Gifford. These facts would indicate that this portion of the stream was extremely old. While it had apparently reached a base level sometime since, it has done but little filling and at present is deepening its channel slightly between Gifford and Union. North of the junction there is a decided change in the landscape. The valley contracts sharply and the flood plain is too narrow to be represented on a map of the scale used in these reports. In this portion of its course almost no alluvium has been deposited. The stream flows over bed rock through a gorge whose walls are rock supported. The convex sides of the bends are often marked by mural escarpments of red sandstone varying from forty to sixty feet in height, crowned by drift bluffs which rise more than 125 feet above low water level. Beyond Steamboat Rock the sandstone ledges are obscured by drift

talus but the restraining bluffs lose none of their precipitousness and range even higher than along the lower course, attaining a height of at least 150 feet above the present channel, between Steamboat Rock and Hardin City, and again between Hardin City and Eagle City. These eminences are largely composed of glacial debris. An impure limestone at the base of the bluff, near the Jackson-Clay township line on the south side of the great bend at Hardin City, forms a shattered ledge some eight to ten feet above the level of the water in the river. The extremely circuitous meanders in the vicinity of Eagle City and Hardin City marks the Altamont moraine crossing. The Gifford terrace is easily traceable to Hardin City, where it has an elevation of thirty-five feet above the flood plain. At Steamboat Rock where it reaches its maximum it is sixty-five feet above the flood plain. The constituent gravels are much coarser at both of these points than at Gifford and Union. At least two other terraces may be noted above this and the stream is engaged at present in cutting one below. At Hardin City the upper terraces are forty-five and seventy feet, and at Steamboat Rock ninety-five and 110 feet, above low water in the river. Iowan bowlders were noted in abundance on the ninety-five-foot bench. Northeast of Eldora the gravel bench, which rises about seventy feet above the river, is probably the continuation of the second terrace at Steamboat Rock. The materials are much finer and stratification planes, though much interrupted, are very prominent. Fragments of these terraces may be viewed at other points. The terrace now forming is already out of reach of high water. It varies from fifteen to twenty feet above low water level. The Iowa Central railway is built on it between Steamboat Rock and the point where the railway leaves the river valley north of Eldora. This terrace is also sought out by the C., I. & D. railway for a mile or two either side of Xenia. In the latter region the bench is in part rock supported. Below Union the Gifford terrace merges with the one now forming and thus continue into Marshall county.

Beyond Hardin City there is a marked change in the topographic features; the bluffs recede from the river, and the contours are markedly softened. The gravel terraces which characterize the valley cross-section in its lower course become less prominent and beyond Eagle City practically disappear. The Eldora sandstone, underlain with shales which

FIG. 24. Elk Run, showing the transition from the gorge to the valley stage; near Iowa Falls.

engender a bold relief, has given place to the limestone of the Lower Carboniferous. The change in indurated rocks is clearly recorded in the landscape. At Eagle City the river has made an incision into the limestone of some forty feet. This state of affairs, although more or less obscured by drift talus, persists to the vicinity of Iowa Falls. Here the stream flows through a limestone gorge which attains a maximum depth of seventy feet at the Iowa Central railway bridge. The retreating drift bluffs rise some fifty feet higher. At this point the stream has been displaced in very recent times. There is a well marked channel south of the Bliss annex, now sought out by the C., I. & D. railway. This depression closely parallels

the present channel to the eastward, and also toward Alden. The so-called "Rapids of the Iowa," or "Iowa Falls," from which the town is named, the canyon-like gorge of the river itself, and its inlets, Rock Run, Wild Cat Glen and Elk Run, all owe their origin to this displacement. In fact the accidental blocking of the old channel by the ice, which necessi-

FIG. 25. "Wildcat Glen," looking toward the head of the gorge, near Iowa Falls, Hardin county.

tated the cutting of a new one, has given the surface a picturesque ruggedness which renders Iowa Falls unique among interior Iowa towns; and for natural beauty it is without a peer. Westward the stream walls are less gorge-like. Low rock walls appear almost constantly on one or both sides of the stream as far as Alden. North of Alden the indurated rocks disappear, the bluffs become more subdued and the stream, soon after passing over into Franklin county, takes on the character of a drift prairie stream. Briefly told the Iowa flows through a more or less close walled gorge from Alden to near its junction with South Fork, where it suddenly emerges into a broad valley with a well developed flood plain, and is terraced from Eagle City to the Marshall county line. Its

minor tributaries partake of the characters of the parent stream, with this exception, that those from the east have well developed flood plains, relatively low gradients and other characters common to maturely developed streams. It may be of interest to mention that above the forks the Iowa river does not receive a single tributary from the west worthy of a name. The area drained is inconsiderable, drawing almost no tribute save from the north and east.

South Fork.—The South Fork, with its tributaries, Beaver and Tipton creeks, drains more than one-third of the county. The South Fork takes its rise in the ponds and swales of Wright county, flows south across Alden township, where it is little more than a series of prairie sloughs and marshes, continues diagonally across Buckeye, Ellis and Pleasant townships, and joins the Iowa in northern Union. From north central Buckeye to the Tipton-Pleasant township line its course is extremely crooked, the stream doubling and redoubling on itself. The principal morainal ridges are crossed in the southeast corner in Ellis and in Tipton townships, and this is also the region of the greatest meanders. The river has cut to a depth of from fifty to one hundred feet below the general upland, but has deposited little alluvium. Near Point Pleasant the river enters a broad, terraced valley, with a flood plain which varies from one to three-fourths of a mile in width, in every way similar to, and comparable with, the valley of the lower Iowa. Only at rare intervals does the stream lay bare the indurated rocks, as in southern Ellis and northern Tipton townships. South Fork, above the junction of Tipton creek, as in the upper course of the Iowa, shows a dearth of small tributaries.

Beaver creek occupies a broad depression behind the extreme advance of the Altamont moraine and is essentially a prairie stream. The lower course is gravel terraced and possesses a mapable flood plain. The stream is not walled in between bluffs as in the case of South Fork, nor does it bear

any evidence of having done any considerable amount of cutting. It appears rather to occupy simply a depression not of its own making. Its branches are symmetrically disposed, and the width of the area drained as compared to its length is about one to three.

The general features of Tipton creek are almost exactly identical with those of the South Fork. It has its source in Hamilton county, cuts a deep and extremely crooked trench across Tipton township, and joins South Fork in west and central Pleasant township. Springs are quite common along both Tipton creek and South Fork, and both streams throughout their entire courses become completely dry or are reduced to detached basins during seasons of protracted drouth. The portions of Honey, Mud and Minerva creeks in Hardin county are essentially prairie sloughs and swales. Honey creek, from Hubbard southeastward, resembles Tipton creek, though it has done less cutting, and its restraining bluffs are less rugged. All are waterless during dry seasons.

Of the tributaries that enter the Iowa from the east all of those outside of the Wisconsin topographic province, flow through erosional valleys of considerable importance when the size of the stream is taken into account, and have well marked flood plains. Elk and Pine creeks show gravel bars where they enter the Iowa, and bear evidence of being older than the parent stream. Bear creek enters the broad valley of the lower Iowa.

Elk Run and School creeks in Hardin township have cut gorges in the indurated rocks and are exact counterparts of the Iowa itself in that region.

Indian creek, a tributary of the Skunk river system, affords partial drainage for ten square miles in Concord township, while tributaries of the Cedar drain half of Ætna and the northeast corner of Clay townships.

Desiccated lake beds of small size are common. Two of the most prominent of these may be observed in Grant township. They occupy the general depression inside of the moraine.

The two best defined lake beds are on sections 13 and 21. The former extends into section 18 in Providence township. These depressions have quite regular boundaries and the sand flats have not yet received sufficient silt and wash to support more than a meager vegetation. Depressions similar to these, and in which water persists throughout the year, appear in Hamilton county.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

Hardin county must be classified as one of the frontier counties of the Iowa coal basin. Coal measure strata are known to extend east of Eldora and Steamboat Rock and are believed to cover more than two-thirds of the superficial area of the county. Norton reports over 200 feet of coal measure strata penetrated in sinking the Ackley deep well. This would make the distribution most anomalous, for according to the field relations the coal measures extend but little beyond Steamboat Rock. The Kinderhook is the country rock over the remainder of the county.

The Pleistocene deposits represent at least three ice invasions, the first of which covered the entire county, the second the northern portion, and the third and last the western two-thirds of the county. Interglacial deposits separate the second and third, while post-glacial deposits may be observed along the principal streams. The taxonomic relations of the formations represented are shown synoptically in the subjoined table.

GROUP.	SYSTEM.	SERIES	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Alluvium. Post-glacial gravels.
		Glacial.	Wisconsin.	Drift.
			Iowan.	Loess. Drift.
			Yarmouth? Kansan	Buchanan gravels. Drift.
Paleozoic	Carboniferous.	Upper Carboniferous or Pennsylvanian.	Des Moines	Eldora sandstone. Lower shales.
		Lower Carboniferous or Mississippian.	Kinderhook	Limestone and dolomite. Shale.

The Pleistocene deposits rest unconformably upon the Paleozoic group and are separated by an enormous erosion interval which probably occupied all of Mesozoic and Tertiary times, for no strata representing this interval are known to occur within the confines of the county. On section 23 of Providence township fragments of a shaly sandstone were obtained from the drift talus along Honey creek which contained Cretaceous fossils; but the blocks bear evidence of ice action and were undoubtedly brought in through that agency.

The surface croppings of the indurated rocks are confined, with a few unimportant exceptions, to the Iowa river and its immediate tributaries.

Rocks older than the Carboniferous are not known to appear at the surface in the county. The nearest Devonian outcrops are in the valley of the Cedar almost a score of miles to the east, and which, according to the Ackley and Eldora wells, dip at least 300 feet beneath the surface before the Hardin

county line is reached. The deep well at Ackley shows the complete Paleozoic series below the Carboniferous. According to Prof. W. H. Norton* the strata penetrated are as follows:

ACKLEY WELL.

(Elevation 1115 feet above tide)

NO.		DEPTH.
87.	Alluvium or drift	....
86.	Shale, fine, blue	100
85.	Shale, fine, blue, somewhat calcareous	115
84.	Limestone, buff, vesicular	135
83.	Shale, fine, blue, slightly calcareous	140
82.	Shale, fine, blue	150
81.	Sandstone, fine, bluish-white, friable	163
80.	Shale, fine, blue	225
79.	Shale, fine, blue	249
78.	Shale, fine, blue	250
77.	Sandstone, as No. 82	260
76	Shale, blue and white, with black ferruginous concretions	265
75.	Shale, fine, blue, somewhat calcareous	290
74.	Limestone, buff, magnesian, highly pyritiferous, containing a little chert	307
73.	Shale, blue, calcareous and limestone, some blue, argillaceous and some gray and purer, fossiliferous, with a few particles of black bituminous shale	320
72.	Limestone, dark gray, magnesian	335
71.	Limestone, argillaceous, non-magnesian, with a fragment of *Atrypa reticularis* Linn.	400
70.	Limestone, light yellowish-gray, argillaceous, slightly magnesian, with some green shale	410
69.	Limestone, light, bluish-gray, non-magnesian	460
68.	Limestone, light yellowish-gray, argillaceous and slightly siliceous	473
67.	Limestone, blue, argillaceous, non-magnesian	500
66.	Limestone, blue, argillaceous, slightly magnesian.	555
65.	Limestone, brown, slightly magnesian	570
64.	Limestone, brown, slightly magnesian	600
63.	Limestone, brown, slightly magnesian	610
62.	Limestone, light brown, magnesian	635
61.	Dolomite	730
59.	Dolomite, with much chert	735
58.	Dolomite, with much chert	740
57.	Dolomite, with much chert	750
56.	Dolomite	751
55.	Dolomite	757

*Iowa Geological Survey, Vol. III, pp. 189-192.

54.	Dolomite	759
53.	Dolomite	760
52.	Dolomite	764
51.	Dolomite, with chert	775
50.	Dolomite, with chert	787
49.	Dolomite, with green shale	797
48.	Dolomite, with green chert.	800
47.	Dolomite, with green chert	803
46.	Shale, green, samples of this from 815 to 960 feet. A hard, brown dolomite, crystalline, cherty, occurs at 875 and 896 feet, thus being interbedded in the shale	960
45.	Limestone, light gray, cherty	975
44.	Limestone, light gray, cherty	995
43.	Limestone, light gray, soft	1015
42.	Limestone, light gray, darker	1040
41.	Limestone, light gray	1080
40.	Limestone, light gray, softer	1100
39.	Limestone, light gray, softer	1150
38.	Limestone, soft, light gray, with some darker bluish-gray	1160
37.	Limestone, light gray	1180
36.	Limestone, light bluish-gray, fossiliferous	1205
35.	Limestone, light bluish-gray, fossiliferous	1230
34.	Limestone, light bluish-gray, fossiliferous	1238
33.	Limestone, light buff	1250
32.	Limestone, dark gray	1257
31.	Limestone, light gray	1275
30.	Limestone, drillings are a fine bluish-black calcareous sand mixed with some of lighter color, highly pyritiferous, considerable argillaceous material and many microscopic particles of quartz.	1300
29	Limestone, bluish-gray, fossiliferous	1320
28.	Shale, green	1325
27.	Shale, bright green, indurated, slaty, highly pyritiferous	1335
26	Shale, bright green, slaty	1350
25.	Sand, white, grains rounded, somewhat uniform in size	1360
24.	Sand, white, grains rounded, somewhat uniform in size	1405
23.	Sand, white, grains rounded, somewhat uniform in size, finer	1415
22.	Limestone, white, subcrystalline	1445
21.	Dolomite, in fine, light yellow powder	1480
20.	Dolomite, with considerable light green shale	1490
19.	Dolomite, buff, with shale and ocherous grains	1500
18.	Dolomite, white, with some chert and quartz and green shale	1505

17.	Dolomite, white, with some chert, quartz and green shale	1515
16.	Dolomite, light yellow	1530
15.	Dolomite, hard, gray, subcrystalline, with grains of quartz	1540
14.	Dolomite, white	1548
13.	Dolomite, hard, rough, light buff, subcrystalline	1550
12.	Sandstone, white, rounded grains, with numerous minute chips of dolomite	1565
11.	Sandstone, as above	1580
10.	Sandstone, light, fine grained, friable, grains rounded, varying widely in size, the largest being about one millimeter in diameter	1595
9.	Sandstone, hard, light gray, moderately fine grained, with considerable green shale	1610
8.	Sandstone, white, grains rounded and resembling the Saint Peter in general uniformity in size; many from seven to nine millimeters, largest over one millimeter	1635
7.	Dolomite, buff	1645
6.	Dolomite, arenaceous or calciferous sandstone	1675
5.	Dolomite, hard, gray, subcrystalline, pyritiferous	1685
4.	Dolomite, light gray	1720
3.	Dolomite, siliceous, gray, with admixture of quartz grains, and some chert	1820
2.	Dolomite, like above, but with more chert	1950
1.	Sandstone, grains rounded, moderately large, with considerable gray dolomite	2000

In his summary Professor Norton refers samples seventy-five to eighty-six, inclusive, to the coal measures. In the light of the known field relations this reference is scarcely tenable. The Eldora sandstone has thinned materially at Steamboat Rock, and the coal-bearing shales are entirely absent. The top of the Kinderhook, hence the base of the coal measures, is 950 feet above tide at Eldora, 970 feet at Steamboat Rock, and 1,110 feet at Iowa Falls. The top of the indurated rocks reached in the Ackley well is 1,010 feet above tide, which would accord very well with the above figures for the top of the Kinderhook and the base of the coal measures. It is also well known that rocks of Kinderhook age appear along Wolf creek at Conrad, in Grundy county, near Hampton, in Franklin county, and were recognized by Calvin* in southwestern Cerro Gordo county. With the present light it would appear

*Iowa Geological Survey, Vol. VII, pp. 170-171.

altogether probable that the upper 200 feet of shales with intercallated limestone should be referred to the Kinderhook. The corrected summary of formations would then stand as follows:†

	Thickness.	Depth.	At top.
Pleistocene	100	100	1,010
Kinderhook	207	307	803
Lime Creek	28	335	775
Devonian unclassified	300	635	475
Niagara	180	815	295
Maquoketa	160	975	135
Galena-Trenton	385	1,360	-250
Saint Peter	85	1,445	-335
Upper Oneota	120	1,565	-455
New Richmond	70	1,635	-525
Lower Oneota	185	1,820	-710
Jordan	210	2,023	-920

The Carboniferous series has not been penetrated at any other point in the county, with the probable exception of the well at Iowa Falls, where a hard, close-textured limestone was reached at about 310 feet below the level of the I. C. and B., C. R. & N. railroad crossing.

GEOLOGICAL FORMATIONS.

CARBONIFEROUS SYSTEM.

The Carboniferous system in the county is represented by two discordant series of beds which are supposed to mark the earliest and latest deposits of that great period, as represented in the immediate region. The first in its surface outcrops is essentially a limestone and belongs the Mississippian series, while the second comprises ferruginous sandstone and shale and is referred to the Des Moines.

†Norton, Iowa Geol. Surv., Vol. VI, pp. 219-220.

THE MISSISSIPPIAN SERIES.

KINDERHOOK.

Only the lowest member of the series is known to be present in the county. Owen* in his reconnoissance survey of the Iowa coal basin recognized the limestone walls of the Iowa river at Iowa Falls and Alden as Carboniferous, but it remained for White† to refer the beds to their proper division, the Kinderhook of Meek and Worthen.‡ Worthen,§ in his discussion of the section at Iowa Falls, tentatively referred the brown magnesian limestone to the Burlington and the lower compact limestone to the Chemung stage of the Devonian. The Kinderhook is believed to envelop the entire county. Superficially it is composed chiefly of a brown, earthy to sugary dolomite, followed by layers of compact, white to gray limestone often exhibiting semi-oolitic facies and sometimes appearing argillaceous or even arenaceous. The principal outcrops are along the Iowa river from Eagle City to Alden. At Iowa Falls there appears to be a decided arching up of the strata and a maximum section of eighty feet is exposed in the river gorge. The limestone beds so far as known are everywhere underlain by a thick deposit of shales, believed to be continuous with the shales which outcrop along the Mississippi river at Burlington. The river gorge at Iowa Falls, taken together with the city well, gives the most important section of the Kinderhook in Central Iowa. The well record shows the following sequence.‖

*Geol. Surv. of Wis., Iowa and Minn., pp. 102-104, 1852.

†Geology of Iowa, Vol. I, pp. 197-198.

‡Am. Jour. Sci. (2), Vol. XXXII, p. 228, 1861.

§Hall, Geology of Iowa, Vol. I, pt. I, pp. 180-181.

‖I am indebted to Mayor W. H. Woods of Iowa Falls for a carefully preserved set of drillings upon which the record is based. Mayor Woods also furnished a complete record of the flow and pumping tests.

	SAMPLE.	Thickness.	Depth.
1.	Drift and weathered material	50	50
2.	Limestone, light-gray, compact	15	65
3.	Limestone, brown, dolomitic, subcrystalline	29	94
4.	Limestone, gray-blue, magnesian, cleavage fragments of calcite not uncommon; compact; grading downward into a light-colored and less magnesian limestone	16	110
5.	Limestone, gray, semi-oolitic in texture	5	115
6.	Limestone, gray-brown, dolomitic and porous; drillings of a gray, compact limestone abundant	11	126
7.	Limestone, brown, dolomitic, with considerable light-colored chert	37	163
8.	Dolomite, gray-brown	7	170
9.	Dolomite, yellowish-brown, sugary	7	177
10.	Sandstone, gray-blue, shaly	7	183
11.	Sandstone, white, friable and very fine-grained	10	193
12.	Sandstone, gray, fine-grained and compact; slightly argillaceous and non-calcareous	14	207
13.	Limestone, blue-gray to yellowish-gray, compact; slightly argillaceous and exhibits an almost earthy fracture	6	213
14.	Shale, plastic, even-textured, light gray-blue and slightly calcareous above	62	275
15.	Limestone, hard, compact (penetrated)	2	277

The mouth of the well is located near the head of Rocky Run gorge and is about thirty-five feet lower than the Burlington, Cedar Rapids and Northern railroad depot. The limestone represented by sample No. 2 is believed to be identical with the white limestone which appears just above the water level along the river. The river section is as follows:

		FEET.
6.	Drift reduced to a heterogeneous mixture of bowlders and fragments of county rock at the face of the escarpment but thickens greatly in the bluffs	0–80
5.	Dolomite, brown, saccarhoidal, heavy-bedded below, but thinner-bedded and much shattered above; often exhibits an earthy fracture when weathered. Numerous casts of *Straparollus obtusus* present in places	20–30
4.	Limestone, light gray, composed largely of shell breccia and containing a Brachiopod fauna; has a mealy appearance; but on close inspection is found to be but slightly concretionary	5
3.	Limestone, gray-brown, is finer textured, more compact and evenly bedded than the above	3

FIG. 26. Gorge of the Iowa river, Iowa Falls.

FIG. 27. Iowa Falls section showing the arching up of the Kinderhook beds below the mill

2. Limestone, light-gray; weathers white and so appears in the gorge walls, exhibits a conchoidal fracture and is heavy bedded.................... 5
1. Limestone, shaly to slightly arenaceous in certain layers; in places forms a slight re-entrant in the cliff-walls; exposed above water level............ 5-10

Combining the well and river sections the Kinderhook is seen to possess a thickness of 310 feet and is composed of

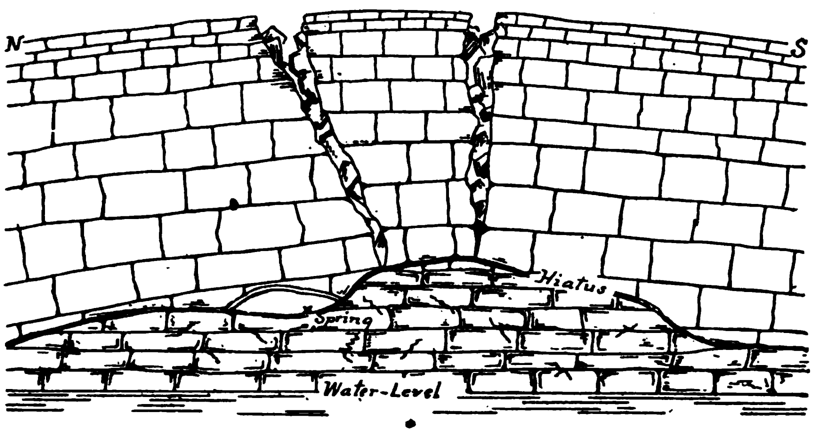


FIG. 28. Section at Ivanhoe quarry showing the local unconformity and the shattering of the upper beds.

alternating beds of limestone and dolomite above, which are underlain by water-bearing arenaceous beds resting on a heavy shale floor.

Below the flouring mills a beautiful flexure in the upper layers may be observed. This anticlinal is of short length and slight amplitude, scarcely more than ten feet, and pitches southward. At this point the Kinderhook beds reach their maximum exposure in Hardin county. To the east and to the west the beds continue in a series of gentle undulations which find expression in the stream channel itself in the numerous recurrence of ripples and pondings. Westward the rocks become sub-crystalline in texture, more shattered, and thinner bedded. At the Ivanhoe quarries the following layers may be viewed:

		FEET.
3.	Drift (of great depth in the bluff)	0- 3
2.	Limestone, grayish white, subcrystalline, very hard and much shattered; thinly bedded	20
	Apparently a local unconformity.	
1.	Limestone, much disintegrated and cavernous. In places a residual clay appears between 1 and 2. Surface very uneven, exposed	6

The river at this point runs nearly due south. At the point where it turns south a ripple appears. Fifty yards below, No. 1 reaches its maximum exposure. No. 2 is rent by a large fissure immediately above the old salient. Just north of the fissure large springs appear, and the water which issues from them is highly charged with iron. The subcrystalline limestone above forms an overhanging scarp. Diligent search was made for fossils in both beds but without reward. Beyond the Ivanhoe quarries to Alden the river flows between low limestone walls varying from ten to thirty feet in height These limestone barriers are almost cut out in one or two instances by coal measure outliers. In Alden the beds greatly resemble No. 1 in the Ivanhoe section. The beds observed were:

		FEET.
3.	Drift, as in previous sections, is thin at the face of the scarp; a number of large granitic bowlders were noted	3
2.	Limestone more or less evenly bedded; appears to be lithologically the same as No. 1; a marly or shaly band separates 1 and 2 generally	12
1.	Limestone, light-gray, hard, sub-crystalline and oolitic in texture. The lower four feet show marked cross-bedding; false beds dip to the southwest; the upper surface is somewhat undulating and dips gently to the south	5

Here, as in the preceding exposures, the beds are much rifted and shattered. Individual layers rarely exceed four or five inches in thickness, and two well developed series of fissures are visible. The fissures of the major series trend north and south, and are apparently parallel to the corrugations, while those of the minor series stand approximately at right angles to the folds. Genetically the two series probably form

but one great system and were formed at the time of rock crumbling.

North of Alden the indurated rocks dip rapidly and were not observed beyond the corporate limits of the town.

Eastward of the Falls limestone, ledges are more or less continually present to Eagle City, where the following section is exposed:

		FEET.
5.	Drift, exposed	5-10
4.	Dolomite, yellowish-browh, much shattered where viewed; contains a few siliceous nodules.........	10-25
3.	Limestone, gray, sub-crystalline and semi-oolitic..	1½
2.	Dolomite, yellow to gray, sugary..................	3
1.	Limestone, gray, oolitic; very similar to the Bedford oolite in texture, and also to the oolite exposed at Conrad, in Grundy county............	4

The base of the section is about five feet above low water in the river. These indurated beds support a bench which rises forty or fifty feet above water level and continues some distance on either side of the wagon bridge. Numerous remains of *Straparollus obtusus*, and several species of Brachiopods, including *Spirifer biplicatus* H. and *Orthothetes irregularis* H., were noted in the oolitic layers. The beds here may be correlated with the upper portion of the Iowa Falls section, and the fossils recognized are identical with those found in the upper oolitic layers of the Kinderhook beds exposed at Rockton quarry and Timber creek, in Marshall county. Beyond Eagle City the beds disappear rapidly, and the surface outcrops of the Kinderhook beds are almost entirely obscured by glacial debris and coal measure talus. At Hardin City, Steamboat Rock, and one or two points between, No. 4 of the Eagle City section is visible and rises some six or eight feet above the water level. In all cases it is greatly weathered and shattered, making its identity difficult to establish. Between Steamboat Rock and Eldora the Lower Carboniferous passes entirely below the stream channel, but rises again immediately south of the wagon-road bridge at Eldora.

Going down stream from the Eldora bridge a weathered dolomite appears in the stream-bed and also in the right bank about sixty rods below the road crossing. The ledges rise eight feet above the water and appear to be identical, both lithologically and faunally, with the upper member at Iowa Falls. Straparollus casts and a cystophylloid coral were found. These beds appear more or less interruptedly from this point to Union, forming low benches on one or both sides of the river. At Xenia, and again between Gifford and Union, the white limestone member is visible. The maximum exposure is south of Gifford, near a small stream which enters the Iowa from the west. The beds exposed to view are:

	FEET.
4. Drift and wash	0-3
3. Limestone, light gray; white, when weathered	0-3
2. Dolomite, yellowish brown, much shattered and unevenly bedded	6-8
1. Dolomite, red-brown, heavy but unevenly bedded, exposed	4-6

Numbers 1 and 2 are, in a sense, complementary. Where one thins the other thickens and the two aggregate twelve feet exposed. Not the slightest trace of organic remains could be found. Southward and southeastward the beds are cut out within 100 yards by the coal measure shales, only to come into view again a quarter of a mile down the branch on the terrace of the Iowa. Beyond Union the Kinderhook beds are carried below the river, but reappear west of Liscomb in Marshall county. The oolitic member appears at Conrad in Grundy county, where the following section is exposed:

	FEET.
5. Drift (modified Kansan probably)	5
4. Limestone, residual, consists chiefly of cherty concretions imbedded in a matrix of greenish clay streaked and mottled with ferruginous and marly material	3
3. Limestone, slightly oolitic, composed essentially of a shell breccia almost identical with No. 1 in the Eagle City section	4
2. Limestone, hard, subcrystalline containing numerous brachiopod casts	2
1. Limestone, typical oolite in heavy beds; a straparollus and a turreted form of gasteropod were noted; also numerous brachiopod casts	5

The base of the section is about four feet below the Chicago & Northwestern railway track and 1,010 feet above tide.

Away from the Iowa and its immediate tributaries, but a single exposure of the Kinderhook is known within the confines of the county. In northern Tipton and southern Ellis townships, low ridges of white, subcrystalline limestone appear along South Fork. The ledges rise eight to twelve feet above the water; form a constriction in the valley and rapids in the stream. Lithologically the beds appear to be identical with those quarried at Alden and vicinity.

Well records from various portions of the county demonstrate that the Kinderhook beds may be reached at from 100 to 250 feet over the entire county.

THE DES MOINES SERIES.

The coal measure sandstones and shales form an irregular lobe which extends entirely across the county from east to west and covers perhaps more than two-thirds of its superficial area. The beds referred to this stage of the Carboniferous consist of an upper heavy-bedded, ferruginous sandstone which often presents conglomeratic to concretionary facies and is cross-bedded throughout; and lower shales which carry some coal and often contain highly calcareous, fossiliferous ledges. The sandstone reaches its maximum development in the vicinity of Eldora, where it attains a thickness of eighty feet, while the shales are more extensive in the southwestern portion of the county.

The floor of the coal measure series is most uneven. At Gifford the top of the Lower Carboniferous is 940, at Eldora 950, at Steamboat Rock 970, Ackley 1,010, Iowa Falls 1,110 and in the southwestern portion of the county it is about 1,000 feet above tide. The Iowa Falls flexure evidently almost cuts out the coal measure beds. Outside of the general area detached basins are known to exist, as at Gifford the "Marble" and the "Honestone" quarries west of Iowa Falls.

The best sections of the Des Moines may be viewed between Xenia and Steamboat Rock along the Iowa river. On the

southwest quarter of section twenty-one, in Eldora township, a cut along the C., I. & D. railway exposes the following sequence:

		FEET.
4.	Drift at the face of the cut almost *nil*, but thickens greatly towards the bluff	0–50
3.	Sandstone much shattered and unevenly bedded, ferruginous	6
2.	Sandstone, medium bedded, darker colored and coarser textured; contains layers conglomeratic. Some concretionary structures seen.	30
1.	Sandstone, heavy-bedded (exposed)	8

Fossil tree trunks (identified by Macbride as Dadoxylon) project from the face of the cut, some of which are more than a foot in diameter. The species has been identified by Prof. T. H. Macbride as belonging to the conifers of Carboniferous times.

Cross-bedding is the rule throughout the section. At Eldora the above section is repeated and beds lower in the series come into view. The Eldora section is as follows:

		FEET.
7.	Drift (on the face of the scarp)	0– 3
6.	Sandstone weathered and shattered; ferruginous, conglomeratic and concretionary; quartz pebbles ranging up to a third of an inch are common. False bedded throughout; some fossil wood fragments present	40
5.	Sandstone, heavy-bedded	10
4.	Talus slope	20
3.	Shale, Carbonaceous	1
2.	Shale, light colored above and variegated below	20
1.	Kinderhook limestone (top about ten feet below the water level)	6

This makes the total thickness of the Des Moines at this point approximate ninety feet. The sandstone above the mill is much less firmly aggregated and lighter in color. The degree of induration and shade of color appear to be a function of the iron constituent. North of the mill and also along the roadway east of the river the sandstone appears to be divided by a thick deposit of plastic shales. East of the river the section is about as follows:

FIG. 29. Buttress of Eldora sandstone, northeast of Eldora along the east bank of the Iowa river.

FIG. 30. Eldora sandstone, showing the effects of wind and water, near Eldora, Hardin county, Iowa.

FIG. 31. Eldora sandstone showing wind erosion. On the line between sections 10 and 15, Eldora township, Hardin county, Iowa.

		FEET.
5.	Drift	5–15
4.	Sandstone, red, ferruginous; same as the red sandstone west of the river	30–40
3.	Shales, variegated, fissile; oxidized to a yellowish brown above but gray-blue to deep blue below. The variegated appearance is due in large measure to thin seams and flattened lenses of fine white sand	12
2.	Talus slope	20–30
1.	Sandstone, soft, friable; similar to the loosely aggregated sandstone outcrop near the mill	10–20

East and southeast of Eldora the ferruginous sandstone appears in the roadways well up to the crests of the hills for a distance of several miles. On the southeast ¼ of the southwest quarter of section 10, Eldora township, a low hill exhibits a beautiful example of wind sculpturing in the Eldora sandstone. Here the sandstone particles are rather loosely aggregated and yield readily to the wind.

Between Eldora mill and Steamboat Rock sandstone escarpments are maintained wherever the river impinges upon its restraining bluffs. The sandstone sections are almost exact duplicates of those already given. Near the Clay-Eldora township line the coal-bearing shales rise above the water level, and owing to the slight resistance offered by these shales to undercutting, mural buttresses are quite the rule. The first escarpment north of the mouth of Pine creek on the east side of the river gives the maximum exposure of sandstone known in the region, and is as follows:

		FEET.
4.	Talus; from what can be seen in a lateral gorge near by, appearing to be made up of the variable sandstone of the Eldora section	40
3.	Sandstone, slightly indurated and in heavy beds, light-yellow	15
2.	Conglomerate, quartz pebbles up to one centimeter in diameter are conspicuous; highly ferruginous and vesicular; concretionary	10
1.	Sandstone, more evenly bedded and conglomeratic in certain bands	40

Here as before the entire section exhibits cross-bedding.

At the sharp angle where the river changes its direction from northeast to south, two thin seams of coal can be seen about five feet above the water level. A thin, sandy parting separates the two veins. Below follow several feet of Carbonaceous shales, highly charged with pyrites occurring as crystal aggregates. There appears to be no stratigraphic break between the overlying sandstone and the coal-bearing shales at this point. The best section of shales in this locality is seen on the south bank of the river, Sec. 5, Sw. ¼ of the Nw. ¼, Eldora Tp. Here three feet of argillaceous limestone appears about three feet above the water level and forms the caprock for the lower coal seam exploited in the basin. The ledge contains the remains of a rich molluscan and brachiopod fauna.

Professor Calvin has identified the following species:

Productus costatus Sowerby (The costæ are finer than on typical *P. costatus.*)

Spirifer cameratus Morton.

Aviculopecten neglectus? Geinitz.

Bellerophon percarinatus Con.

B. urii Fleming. *B. carbonarius* Geinitz.

Naticopsis subovatus.

Soleniscus newberryi Stevens.

Straparollus pernodosus M. & W.

Orthoceras rushensis McChesney.

The upper coal seam occurs some twelve to fifteen feet above the ledge separated by shale and fire clay. At the bridge the beds rise about ten feet higher, eastward from which the beds dip rapidly and the lower vein disappears below the river 100 yards east of the bridge. Fragments of argillaceous sandstone containing Cretaceous fossils were found at the base of the bluff by Professor Woodford, who still retains them in his collection. Much prospecting has been done on both sides of the river and considerable coal has been mined. The beds are lenticular and run from nothing to five feet in thickness. South of the great bend in the river the contact

between the sandstone and shales is very uneven and bears some of the characteristics of an eroded surface. This suggestion is borne out by mining explorations, the coal seams being cut out abruptly by the overlying sandstone. This unconformity is not believed to be general.

At Steamboat Rock the sandstone has thinned greatly and the shales are entirely absent. An escarpment south of town shows forty feet, while along Elk creek low overhanging walls appear, rising ten or twelve feet above the water. The sandstone has not been recognized beyond this point. The Iowa river gorge continues strong beyond Hardin City, though the character of the walls is almost wholly obscured by the great thickness of drift and talus. As has already been mentioned there is a marked topographic change between Hardin City and Eagle City, which is believed to be due to the cutting out of the Des Moines and to mark the appearance of the Mississippian series. Eastward from Steamboat Rock the coal measure shales appear on the northeast quarter of section 3, where the wagon road crosses Pine creek. A terrace thirty to forty feet in height appears to be supported by indurated rocks.

Between Eagle City and Iowa Falls the coal measures are entirely superseded by the Lower Carboniferous. West of Iowa Falls at the "Honestone quarries" where the river crosses the line between sections 14 and 15 in Hardin township, fifty feet of shales and sandstones appear. The section is as follows:

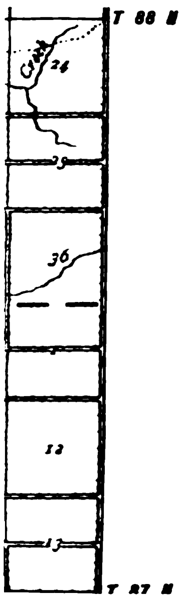
		FEET.
5.	Drift	40-90
4.	Sandstone, fine-grained, slightly argillaceous, breaking up in large blocks and forms a projecting ledge	2- 5
3.	Shale, arenaceous, blue-gray and but slightly indurated; certain hard layers appear throughout the section	30
2.	Shale, blue, fissile; in some places almost black	15
1.	Limestone, dolomitic; in many places a cherty layer appears on top. The limestone is weathered, a red-brown; arenaceous; minimum exposed above water	1

Large blocks from the sandstone ledge appear in the river and partially obstruct the channel. It is from this ledge that the material used in the manufacture of honestones is obtained. The beds cut out in less than a quarter of a mile but appear again in the southeast quarter of section 16 in Alden township. This marks the last exposure of the Des Moines along the Iowa within the limits of the county. Another detached basin occurs in the vicinity of Gifford, where ten to fifteen feet of shales are visible. No other coal measure exposures are known west of the Iowa and away from the immediate vicinity of the river. Well sections show the presence of the Des Moines over the southwestern portion of the county and in many instances some coal is penetrated.

THE PLEISTOCENE.

The Pleistocene deposits consist of a most complicated mixture of bowlder clays, silts, sands and gravels, and rest unconformably upon both series of indurated rocks. They cover the entire surface of the county save where removed by the streams, and it is in this incoherent complex that the principal features of the landscape are expressed. The series varies greatly in thickness, but ranges from zero to 300 feet, and averages more than 100 feet for the entire county. With a single exception the series has been completely cut through only in the immediate vicinity of the Iowa river and in the province of the loess-Kansan.

According to well sections the greatest thickness, as might be expected, is reached in the western tier of townships and in the belt covered by the principal moraine; especially in Providence township. In Alden township, starting with section 5 and progressing east of south to section 34 and continuing across Buckeye to sections 31 and 32, the drift varies from 150 to 235 feet. The western tier of sections in Alden show almost as great a depth of drift. In Providence township the wells reported give the drift an average depth of nearly 200



BY

S. W. BEYER

1900.

Scale $\frac{1}{125,000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

feet; the greatest depths recorded are in the Gibbs and Flemming wells located in sections 19 and 17 respectively, where the Pleistocene deposits approximate 260 feet.

Ash as been previously stated, at least three till sheets, separated by interglacial deposits, are known to exist in the county.

THE KANSAN.

Glacial deposits older than the Kansan have been recognized at widely separated points to the east and south and it is highly probable that an earlier ice sheet invaded Hardin county, but deposits representing such an invasion have not been certainly recognized. Recurring gravels in certain well sections suggest the presence of a multiplicity of drift sheets greater than would seem to be warranted by the surface outcrops, though the true presence of a pre-Kansan till cannot be demonstrated. Another line of circumstantial evidence is the wide distribution of heavy gravel beds above the indurated rocks, which would greatly strengthen the belief in a pre-existing till at no great distance. The Kansan is known to cover the entire county, but is everywhere more or less obscured by later deposits. In the loess-Kansan province the Kansan is covered with a thin veneer of interglacial silts, but is, in the main, responsible for the topographic features of the region. In the western two-thirds of the county its existence is almost entirely blotted out by the Wisconsin till, and the only source of information concerning it is gained from artificial excavations. Well records show that this drift sheet varies from zero to 100 feet in thickness; perhaps averaging fifty feet for the entire county. The best natural exposures are to be found along the Iowa river and away from the river, in Providence, Union and Eldora townships. The Kansan till consists of an upper thoroughly leached, strongly oxidized and weathered portion which is usually a deep reddish-brown in color; and a non-weathered, non-leached lower portion which is generally some shade of blue or green and is colloquially known as "hardpan." Bowlders are not especially numerous. Those

present rarely exceed one or two feet in diameter and greenstones are the prevailing type. The granitic bowlders are commonly in an advanced stage of decay and disintegrate rapidly when loosed from their matrices, often crumbling at once when exposed to the air. The weathered portion measures from five to twenty feet in thickness and graduates insensibly into the unoxidized hardpan below. The Kansan surface is profoundly stream molded and is, as a consequence, perfectly drained.

THE BUCHANAN GRAVELS.

Deposits referable to the above formation are not conspicuous. In the loess-Kansan area the loess is usually separated by a more or less constant gravel layer. A well on section 29, in Union township, was reported to have penetrated a definitely marked gravel bed below the loess, and this is quite the rule for western Union and eastern Providence townships. In the area covered by the Wisconsin drift wells not infrequently encounter heavy beds of gravel from forty to 100 feet below the surface and above the heavy blue till of the Kansan. In central Buckeye township well drillers report from twenty-five to fifty feet of these gravels. Their stratigraphic position would suggest their reference to the Buchanan as highly probable.

THE IOWAN.

The Iowan drift is typically developed in eastern Ætna and Clay townships. Iowan bowlders have a much wider distribution. Immense bowlders of gray and red granites are found in great profusion along the Iowa river as far west as Eagle City, and scattered blocks well into Hardin township, are not uncommon. One of these ponderous invaders may be seen near the line separating sections 27 and 28 north of the river. The most marked characteristics of the Iowan in Hardin county, as elsewhere, are its almost monotonously level surface and its train of giant bowlders. The till matrix is comparatively unimportant and much wasted away by subsequent

changes. The bowlders form the most conspicuous features of the landscape and are found far beyond the verified limits of the till. In eastern Eldora and even in eastern Union township, granite blocks of heroic size may be observed flanking the more pronounced eminences. In other counties where the drift of this stage is more typically developed, it is seen to be composed of a yellow, often more or less porous and jointed, partially oxidized and leached till, which sometimes grades downward into a gray-blue bowlder clay, aggregating a total thickness of from one to fifteen or twenty feet. Small pebbles and bowlders are not uncommon but granite blocks of enormous size and perfect freshness are characteristic.

THE LOESS.

Coincident with the maximum extension of the Iowan ice was a period of land depression, and as a consequence sluggish drainage. The winds and the waters co-operated in depositing outside of the ice margin, a veneer of clays and silts over hill and dale alike. These silty deposits take the name loess, which was first applied to similar deposits along the Rhine in Germany. The loess consists of a structureless or indefinitely bedded mass of yellowish clay or sandy silt, and usually contains numerous lime balls or concretions. It is highly siliceous and a high percentage of lime is generally present in a finely divided state, sufficient to produce rapid effervescence when weak hydrochloric acid is applied. Root casts and gasteropod remains are common, and in many places are extremely abundant. The loess is easily distinguished from the drift by the absence of pebbles and bowlders, its even textured character, lime balls and faunal remains. Its presence tends to strengthen the drift contours where it occurs. While loess erodes easily, it possesses the peculiar property of maintaining a vertical scarp an indefinite length of time, even when exposed to direct weathering agencies. The loess reaches its best development in the county, and is most easily observed in Providence, Union and

Eldora townships. It is thickest here, as in other counties where it occurs, along the principal drainage lines. The best exposures in the region are in the vicinity of the town of Union, west of the Iowa river. North and west of Union the loess extends well down the hill slopes and exceeds twenty feet in thickness. Many local wells formerly drew water from the sub-loessial sands; and the coarse grass and seeping springs mark the loess contact on the Kansan drift in the ravines and draws. Outcrops of the loess may be observed well across Providence township, and the loess undoubtedly continues under the Wisconsin drift and connects with the deposits near Ames in Story county. On the southeast quarter of section 6 in Providence township the loess appears in a cut along the roadway overlain by twenty feet of Wisconsin drift and resting upon the oxidized Kansan. Also in section 16, in a road cut, eight feet of loess is visible. The deposits at these exposures are closely set with root casts, some of which measure four inches in diameter. Loess concretions are numerous and a few gasteropod shells were noted, the most common being a species of Succinea. These are the most westerly exposures in the county. In Eldora township the loess has been observed as far north as Eldora, where it is used by the clay manufacturers.

THE WISCONSIN.

Closely following the loessial stage the western two-thirds of the county was invaded by a great ice tongue which extended down from Wisconsin and Minnesota to central Iowa, the apex of the tongue reaching Capitol Hill, Des Moines. The eastern limit of this great ice lobe is marked by a complicated series of ridges and knobs and their complementary swales and ponds. Its outline is more or less lobular and the eastern margin passes across Hardin county in an almost north and south direction. The marginal belt, which varies from two to five miles in width, and is continuous with the moriane in Marshall, Story and Polk on the south, and with the moraine of Cerro

Gordo and Worth to the north, is known as the Altamont moraine. As in Story county, certain more or less broken chains of ridges and knobs concentrically arranged may be noted within the area outlined by the Altamont. These concentric chains indicate halts in the retreat of the ice lobe and have been designated recessional moraines by the leading authorities in glacialogy. The general surface or ground moraine of the Wisconsin has undergone very little modification since the retreat of the ice. As has been previously mentioned the surface presents a pitted, hummocky appearance which is entirely independent of present drainage lines. The streams bear evidence of very recent establishment, in their narrow, high-walled channels, high gradients, dearth of small tributaries and the presence of extensive undrained areas. The drift material is markedly fresh; being little leached or oxidized. In fact the *tout ensemble* of characters mark the Wisconsin as being extremely youthful.

The Wisconsin in Hardin county plainly exhibits an earlier and a later phase. The surface tills on New Providence and Eldora Hills are decidedly different from the surface materials which cap the hills and ridges in Tipton, Ellis and Jackson townships. In the first oxidation and leaching have progressed to a considerable extent. In numerous road cuts acid tests failed to give an appreciable reaction to a depth of from two to four feet. While in the latter localities the materials even at the surface give strong effervescence on the application of dilute hydrochloric acid. The surface features themselves, present as marked contrasts. In the former area drainage lines have made considerable progress and ponds and kettles are approaching extinction. In the latter, drainage is strikingly imperfect and the surface is but little molded. It is at present impossible to trace definitely the line of separation between the older and newer Wisconsin drift. The boundary may be said to pass approximately from the Grant-Concord line on the Story county boundary, across Grant township near its middle; crossing Tipton creek at the great bends in Tipton

township, and South Fork at the great bends in Tipton and Ellis townships; continuing north of east across Beaver creek west of Owasa. From this point its course is very uncertain, but it probably continues east of north across the county. This is believed to be the northward extension of one of the limbs of the Gary moraine of Boone and Story counties. Another recessional moraine, more or less interrupted, can be observed in the extreme western portion of the county. South of Radcliffe a chain of subdued ridges appear along the Hamilton-Hardin county line. North of Radcliffe the series of ridges take an east of north trend and are responsible for the complicated meanders in the South Fork for northeast Buckeye township and continue northward between Alden and Iowa Falls, a spur extending south of the latter place.

Aside from the moraines numerous sand and bowlder knobs rise above the general level and tend to break the monotony of the drift plain. These prominences are most numerous in the immediate vicinity of the morainal tracts but are widely distributed over the intramorainal areas. In certain instances the constituent sands and gravels show stratification planes evidently due to running waters. Such eminences exhibit a gregarious tendency; they are known as kames, and are very generally conceded to be the work of sub-glacial streams. One of the most conspicuous groups of kames in the county may be observed south of School creek in sections 15 and 16 in Hardin township.

The Wisconsin drift is composed of a most heterogeneous assortment of clays, silts, sands and gravels, with a liberal sprinkling of bowlders of medium size, all admixed in a most complicated manner; and taken as a whole the composite is known as till or bowlder clay. The clay and silt elements predominate. Below the humus charged surface, the Wisconsin till is of a pale, straw yellow, full of lime blotches, but slightly oxidized and almost wholly unleached. It grades downward into a gray blue till which is wholly unaffected by the weather. The upper slightly weathered portion varies

from two to four feet in thickness for the later Wisconsin; from five to fifteen feet for the earlier.

The total thickness referable to the Wisconsin stage is difficult to ascertain accurately. Natural sections exhibiting the drift sheets are rare or almost entirely unknown in the county because of the inability of the drift to maintain a clean cut escarpment. Along water courses which have cut through one or more of the drift sheets, talus slopes and landslides have effectually obscured the real nature of the valley walls. The best evidence obtainable comes from artificial excavations. Drillers' records show that gravel beds below the upper till are pretty generally distributed over the county. They also record a buried wood zone which is believed to be at or near the base of the Wisconsin drift. Basing the separation of the Wisconsin from the older till sheets on the above criteria the Wisconsin drift is found to vary from forty to eighty, or even 100, feet in thickness. In the vicinity of the court house in Eldora it is at least forty feet thick, while in the bluffs about Hardin and Eagle cities, and in the western tier of townships, much greater thicknesses, up to 100 feet, are reported.

Development of the Iowa river system.—From a careful study of the Pleistocene map it is obvious that the history of the drainage of the county is intimately associated with the Wisconsin drift. The Iowa proper, above the confluence of the South Fork, is evidently a superimposed stream and was established after the Wisconsin advance, while the channel below the junction meanders through a broad alluvial valley and is antecedent in character. That the upper course is superimposed and younger than the lower course is based upon the following facts: First, the stream flows through a narrow rock-walled and rock-bottomed gorge from Alden to the junction and has laid almost no alluvium. At Iowa Falls the canyon is no wider than the stream channel. Second, the all but total absence of tributaries worthy of a name from the west is certainly significant. The bluff line is broken only

by V-shaped ravines and sharp defiles from this quarter. From the east Elk and Pine creeks enter through well developed alluvial valleys more in harmony with the lower course of the Iowa, and were evidently established prior to the upper course of the larger stream. Third, the striking coin-

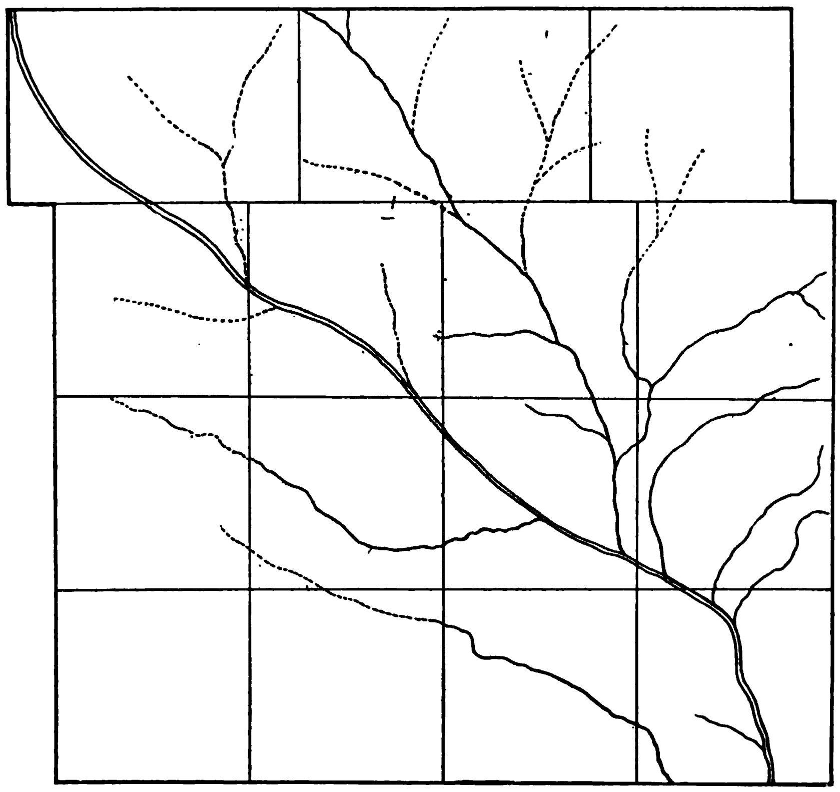


FIG. 32. Sketch map exhibiting the pre-Wisconsin drainage system, somewhat diagrammatic.

cidence of the position of the present stream with the Wisconsin ice front from the point where the river takes its southerly course, points to the same conclusion. The morainal barriers are skirted by the phenomenal detours of Eagle City and Hardin City. Fourth, the departure from the northwest-southeast course so common to the chief drainage lines of east central Iowa must be considered; and fifth, the South Fork, in the main, and Beaver creek in its lower course, flow through broad depressions, have comparatively low gradients,

and have the general characteristics of streams occupying old valleys which have been partially reopened. At numerous points along South Fork, in Buckeye and Ellis townships, artesian flows are obtained from heavy gravel deposits, presumably the pre-Wisconsin stream gravels which were her-

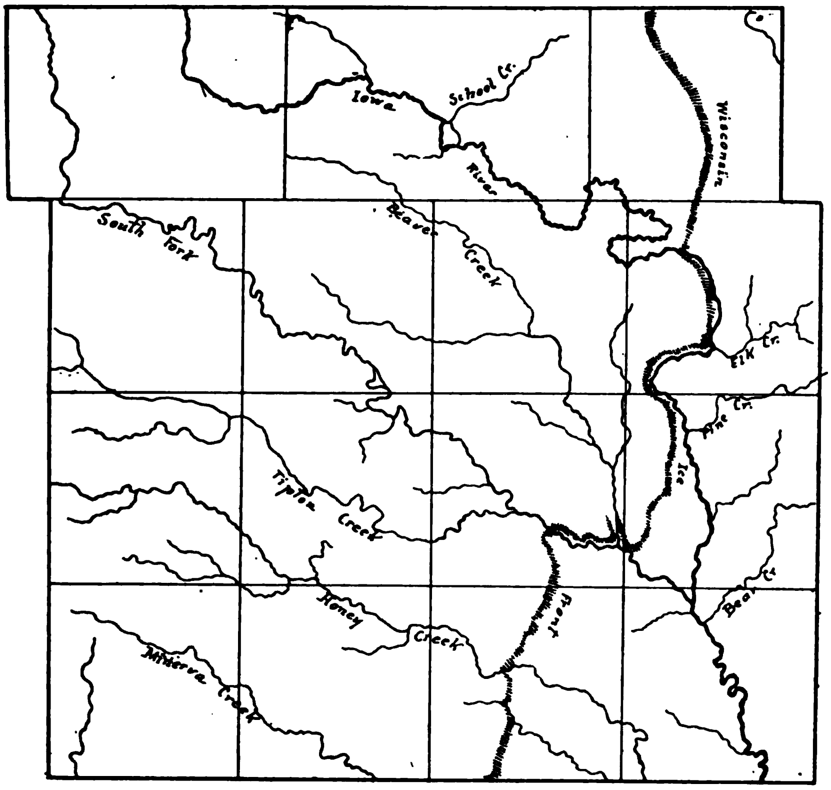


FIG. 38. Sketch map showing the relation between the present drainage lines and the Wisconsin ice front.

metically sealed in by the later drift debris. From the above facts it is believed that the pre-Wisconsin Iowa occupied, more or less approximately, the course of South Fork, and perhaps received tributaries of considerable size from the north and east. A large tributary may have occupied the depression of Beaver creek, and Elk and Pine creeks were extended to their junction with Beaver creek or South Fork. On the advance of the Wisconsin ice these maturely adjusted

streams were pushed from their courses, and the tributaries flowing to the south and west, being obstructed, would naturally be diverted and flow along the ice front and, eventually, by their coalescence establish a new stream. The newly formed stream would proceed to cut a channel, and upon the subsequent retreat of the ice would find itself caught between self-made barriers, and unable to reopen and resume its old course, now more or less completely filled by glacial debris. The tributaries would be betrunked while their upper courses would remain unaffected. The former channels of the leading streams would be, perhaps, partially reopened, but would be occupied by waterways of minor importance because despoiled of their strong tributary system from the north and east. This, in brief, is believed to have been the history of the Iowa river system in Hardin county.

Stream terraces.—All of the principal streams of the county flow from the Wisconsin drift plain, and all exhibit one or more series of gravel terraces. The greatest of the gravel trains is genetically related to and has its source at the Gary moraine. This terrace is best seen in the vicinity of Gifford, along both the South Fork and the Iowa proper. The bench along South Fork rises from twenty feet at Gifford to nearly thirty to the westward above the flood plain of the present stream. The gravels are coarsest above and show more or less evident but interrupted stratification planes throughout. The bedding is at all conceivable angles. The gravels vary from fifteen to twenty feet in thickness and rest on a basement of bowlder clay, the top of which rises from five to twenty feet above low water level. On the Iowa proper the constituent materials are much coarser, indicating a higher gradient, but the bench is much narrower and more fragmentary on account of the gorge-like character of the valley. Steamboat Rock is built principally on this bench, which is fifty feet above the flood plain. Terraces referable to this system may be found along the two leading tributaries of

South Fork, and also along Honey creek. Below the junction of South Fork with the Iowa the Gary terrace continues but fades out toward the Marshall county line.

Fragmentary terraces above the Gary may be noted along the Iowa but are of little importance. A terrace below the Gary may be noted along the Iowa, South Fork and Tipton creeks, in which the streams to-day are engaged in cutting. It rises from five to fifteen feet above the present flood plain. The Iowa Central has sought it out for a roadbed below Steamboat Rock.

Post-Wisconsin deposits.—Deposits later than the Wisconsin are unimportant in Hardin county. With the exception of the Iowa below the junction, all of the streams have been busily engaged in down cutting and have had little time or opportunity for the building of flood plains. With the above exception South Fork and the lower course of Beaver creek present the only mapable alluvium.

Along the Iowa in Marshall county and the Skunk in Story, wind deposits crown their eastern bluffs and attain some importance. The materials which constitute these deposits may be traced directly to the river flood plains. In Hardin county all the alluvial deposits are unimportant; the wind deposits are not worthy of mention.

ECONOMIC PRODUCTS.

COAL.

Coal mining has been carried on more or less intermittently in the vicinity of Eldora during the past forty years. Two seams have been developed to some extent, though mining operations have been confined chiefly to the lower one. The upper seam runs the more evenly and varies from a mere "blossom" to eighteen inches in thickness. The lower seam is reported to attain a maximum of from four to five feet in thickness. The general dip of the strata is to the southeast and both seams where mined lie above the level of the water in the river. Mining operations have ceased for some years

and accurate information is difficult to obtain. In 1857 Whitney* visited the area when the mines were active and reports the following sequence on section 5 in Eldora township.

	FEET.
Ferruginous sandstone, about	50
Black slate	5½
Coal	3½ to 4
Black shale (exposed)	7

Whitney reports that the bed of coal shows numerous slips passing through it from top to bottom, at distances of a few feet and that the beds dip rapidly southward away from the river. North of Eldora on either side of the wagon bridge in section 5 the following beds may be observed:

		FEET.	INCHES.
7.	Drift	30-50	
6.	Sandstone, ferruginous, conglomeratic and concretionary; cross-bedding evident on weathered surfaces	30-40	
5.	Talus slope and shale more or less obscured	3- 5	
4.	Coal		2-12
3.	Shale, black; the lower portion to the westward becoming strongly calcareous, loses its fissility and is highly fossiliferous	8-10	
2.	Coal	2- 3	
1.	Fire clay, exposed at or about water level		

This is believed to be about the average section for the Eldora basin. East of the bridge the coal seams dip rapidly and soon disappear below the river. Much prospecting has been done to the east and north of this point and considerable coal has been taken out. Dismantled diggings and deserted dumps alone bear witness to the former mining activity of the region. The coal cuts out rapidly to the westward and throughout the basin was extremely "pockety" in its distribution.

In other portions of the county but little or no systematic prospecting has been done. It is quite certain that the larger portion of the county is covered by the coal measures, and it is highly probable that workable coal will yet be found within its borders. Well drillers record the encountering of coal seams at

*Hall, Geology of Iowa, Vol. I, p. 269.

numerous points in the southwestern portion of the county, and in view of the fact that coal has been mined in the vicinity of McCallsburg in Story county this would appear to be a legitimate field for the intelligent prospector.

CLAYS.

Hardin county is abundantly supplied with crude material suitable for the manufacture of pressed, paving, fire and common brick; draintile, sewer pipe and pottery. The clays available are confined to the eastern and northern portions of the county. The southeast quarter is supplied with an almost continuous veneer of loess which is adapted to the manufacture of common and pressed brick, and draintile; while the coal measure shales outcrop at various points along the Iowa river from Gifford to Iowa Falls and furnish an abundance of material suitable for the manufacture of ornamental and the more refractory wares.

The clays at present utilized belong to two widely separated periods, and comprise the shales and shale-clays of the Carboniferous and the clays and silts of the Pleistocene.

The Carboniferous shales.—Shales belonging to this period are referable to the Des Moines stage. Important outcrops appear in the vicinity of Iowa Falls, Eldora and Gifford, but only those at the last two points are utilized. The Des Moines shales here, as in other portions of the state, comprise a complex series of beds varying greatly in composition and texture. Beds of uniform texture and composition rarely exceed a few feet in thickness, and in order that the pit may be operated economically the entire section must be utilized. There must be a thorough blending of the constituent layers in the process of manufacture, or else the ware lacks uniformity in texture and color. Pugging and tempering is more or less imperfectly done in most instances, hence the mottled appearance of the finished product where shale clays have been used.

None of the clay-working establishments use shales exclusively, so that while the two classes of crude materials are so

distinct stratigraphically and genetically, they are not kept separate in the present methods of manufacture.

Eldora.—The clay-working center of the county is Eldora and vicinity. Three factories are located within the corporate limits, while a fourth lies two and one-half miles southeast of town.

The Eldora Pipe and Tile company.—In 1893 the Eldora Clay Manufacturing company established an expensive plant along the Iowa Central railway, just north of the C., I. & D. crossing. The company undertook not only the manufacture of brick and draintile, but equipped themselves to turn out sewer pipe, flue pipes, linings and tops, lawn vases, architectural terra cotta, wall coping and fire-proof building blocks. The works were housed in good buildings and expensive modern machinery was installed. On account of the general business depression and unfortunate management the plant was practically idle during 1897 and 1898. In 1899 the Eldora Pipe and Tile company assumed control and the plant is being thoroughly renovated and overhauled. Brick and tile were the only products during the past year, but the new management hopes to resume the manufacture of sewer pipe in the near future. Both coal measure shales and Pleistocene clays are used. The former are obtained from the valley of South Fork some three and a half miles south of the factory. The shales are hauled by wagon from the pit, loaded on cars, then transferred by rail to the factory. About twelve to fifteen feet of shales are available. The layers of shale are variable in color and texture but when thoroughly mixed give promise of a creditable product of both sewer pipe and paving brick. A vein of fire clay is exposed in the section which, when wrought alone, gives a good quality of fire brick. For builders and tile the shales are mixed with alluvium or loess, the former obtained from the river flood plains and the latter east of Eldora hill. The plant is equipped with a Stevenson dry-pan, a Fate-Gunsaulus brick and tile machine, a two-story steam-heated drying house and three round down-draft kilns.

The equipment also includes a Stevenson wet-pan and a Stevenson press for the manufacture of sewer pipe.

The Eldora Tile works are located along the Iowa Central tracks south of the Eldora Pipe and Tile company's works. Common brick and draintile are the only products produced at present. The crude materials developed are obtained from the Pleistocene and the coal measures. The two are blended in the proportion of two parts loess to one of shale. The former pit is located about three-fourths of a mile northwest of the factory beyond the Wisconsin drift margin, and the latter is obtained from the shales east of the Iowa river along the wagon road. As in the case of the Eldora Pipe and Tile company all of the raw material must be hauled. The plant is equipped with a "Little Wonder" stiff mud machine, open drying sheds and three round down-draft kilns.

The X, Y, Z Brick and Tile company is located in the southeast part of town, just east of the C., I. & D. railway. The plant was established in 1893, is well equipped and conveniently arranged. A Nolan & Madden No. 5 B. machine is used with the pug mill. No crushing is required to prepare the clay. A large steam drying room, two down-draft kilns of 60,000 brick capacity are used for drying and burning the ware respectively. Tile from three to twelve inches in diameter and common brick are the sole manufactured products. The raw material is obtained in the immediate vicinity. The pit is located in a ravine and exhibits the following section:

		FEET.
4.	Loess, slightly arenaceous below	10
3.	Drift, yellowish and contains numerous bowlders of considerable size	6
2.	Till, blue, joint; bowlders not numerous	4
1.	Shale, blue-black (coal measures)	25

Brick are made out of No. 4, while Nos. 2 and 4 are mixed in the manufacture of draintile. No. 1 has not been utilized to any great extent as yet. The brick burn to an even cherry red color, very pleasing to the eye.

Other factories located in Eldora have flourished during the past quarter of a century but those described are the only ones active at present.

About two and a half miles southeast of town is a factory operated by E. D. Perkins. Here, sand rolled brick are made from a mixture of loam and loess, in the proportion of one part of the former to four of the latter. The brick are dried in open sheds and burned in an open kiln.

Pottery making has been an industry carried on more or less intermittently in this vicinity for nearly a third of a century, but no manufactured products have been put upon the market for several years. The raw material was obtained from shallow pits about one-half mile north of Gifford, and was coal measure in age. Four feet of soil and impure clay was passed through before reaching the worked bed, which was claimed to be nearly twenty feet in thickness. The upper six feet was reported to be of a dark color and was mixed with the under clay in order that the best results might be obtained. The drab clay alone moulded easily but did not take a salt glaze, nor stand a high temperature as well as did the blue clay.

The fire clay below the lower coal seam, north of Eldora along the Iowa river, has a good reputation as a potter's clay, but is no longer utilized. All kinds of stoneware, glazed and unglazed, were formerly put out. The glazing was accomplished by the introduction of salt into the kiln, or by the use of the Albany "slip clay." The round up-draft potter kiln was used in burning. Some years since a considerable quantity of crude clay was shipped from this region to potteries in and out of the state. Nothing was reported, however, in this line for 1898.

Gifford.—The Jonker Brick and Tile company operate works just east of the Iowa Central railway and south of the C. & N. W. crossing. Tile from three to ten inches in diameter and a few brick are the only manufactured products. The raw material is obtained from a cut along a small stream just

south of the town, where the following sequence of beds is exposed:

		FEET.
2.	Drift, on north side of pit arenaceous to gravelly below, loosely compacted, dirty yellow	0–3
	On south side of pit, a heavy, blue, joint clay, oxidized along joints a red-brown	0–3
1.	Shale, deep blue (almost black when wet), considerably oxidized where unprotected by drift; becomes arenaceous eastward and contains but little iron	8

The raw material is wet at the yard and run through a Wallace crusher or stone separator, then carried to a Kell & Son's auger machine. The drying sheds have adjustable sides and by care the moisture can be carried off without checking the ware. Two round down-draft kilns of about 10,000 four-inch tile capacity are used in burning. Alluvium and hillside wash are mixed with the shales to heighten the color. The product bears an extremely mottled aspect, owing to imperfect mixing of the raw materials.

Iowa Falls.—The Iowa Falls Tile company operate works located one-half mile east of town and south of the I. C. and B., C. R. & N. railway tracks. The raw material is obtained from a small draw which makes back from the Iowa river and is obviously post-Wisconsin. It consists of a prairie loam and an ash-gray to blue clay, both of which belong to the Wisconsin till sheet. The clay is highly calcareous and slightly arenaceous. The entire deposit appears to be due to a partial filling of the ravine from the wash carried down from the higher ground.

The clay is run through a Wallace crusher into an H. Brewer machine. Some care must be exercised in drying to prevent checking and the ware is burnt in round down-draft kilns. Draintile is the only product manufactured.

From the above brief description of the clay manufacturing plants in Hardin county it is obviously apparent that the industry lacks much of its complete development. The county is rich in crude materials, and yet the total value of the manufactured products marketed in 1898 was less than

$17,000. Of this value three-fourths came from the top clays of the Pleistocene. The shale clays can scarcely be considered more than opened to development. There is but a single dry-pan in the county. Most of the factories are unfortunate in the matter of location. Unlimited quantities of coal

FIG. 34. "Honestone Quarries," a local coal measure basin along the Iowa west of Iowa Falls, resting unconformably upon the Kinderhook. The sandstone ledge appears well up in the section and numerous blocks appear in the stream channel.

measure shales are in sight along South Fork south of Eldora, immediately adjoining the Iowa Central railway, and yet the factories which are developing them are located three and a half miles to the north in Eldora. Almost inexhaustible quantities of shales appear along the Iowa river west of Iowa Falls, and yet not a brick has been molded from them. The sequence of beds exposed on the northwest quarter of section 14, in Hardin township, is as follows:

	FEET.
Drift (of variable thickness)	50
Shale, arenaceous	10
Shale, sandy to shaly sandstone	3
Shale, variegated, blue to yellow	4

	FEET.
Sandstone, fine grained, gray-blue, forms a projecting ledge	2
Shale, fissile, gray-blue to deep blue when wet	30
Unconformity.	
Limestone, cherty and much weathered Exposed above water in river	5-10

The above section can be utilized in its entirety, save the sandstone ledge and the drift, in the manufacture of vitrified brick, building brick, and tile. Near the lower portion of the section certain layers are believed to possess the necessary properties of a potter's clay. It seems reasonably certain that with the present demand for all kinds of clay goods these deposits will not long remain undeveloped.

BUILDING STONE.

In 1898 about $7,400 worth of all kinds of stone used for structural and road purposes, was marketed in Hardin county. The entire output came from the Lower Carboniferous and consisted of limestone and dolomite.

Two distinct geological periods have contributed structural materials to the natural resources of the county, the Kinderhook and Des Moines of the Carboniferous, and the glacial stage of the Pleistocene. The Kinderhook is the only producer of stone in commercial quantities. Quarries which work the Kinderhook beds are located along the Iowa river at Gifford, Eagle City, Iowa Falls and Alden. Small quarries have been opened near the north line of Tipton township along South Fork. In fact nearly all of the Kinderhook outcrops have been worked more or less intermittently for many years. The most important quarries are located near Iowa Falls.

Iowa Falls.—East of the I. C. railway bridge three quarries are now actively operated on the north and east sides of the river. These are known as the Talbot, Purcell and Biggs quarries, respectively. The sections exposed and the methods employed are practically indentical in all of the quarries. Hand methods, only, are in use, improved machinery having yet to make its appearance. The section exposed at the Biggs quarry is as follows:

		FEET.
6.	Drift, very thin; consists chiefly of a bowldery gravel	0–3
5.	Dolomite, brownish-buff, much weathered in places and presents an arenaceous or earthy facies.......	4
4.	Limestone, white, oolitic, fossiliferous..............	6
3.	Limestone, blue, compact, of firm texture and very brittle..	3
2.	Limestone, white; lower three feet very compact and brittle; fracture conchoidal to uneven, contains numerous blebs of crystalline calcite; almost lithographic in texture..............................	5
1.	Limestone, gray, dolomitic, very slightly arenaceous to argillaceous; exposed...........................	5

The quarry methods in vogue are to drill deep holes vertically, nearly parallel to the face of the cliff, and then to use

FIG. 35. Section of Kinderhook beds exposed at the Biggs' quarry.

heavy charges of explosives to shoot loose the ledges. This leads to great shattering, and scarcely more than thirty per cent of the entire section can be used for dimension stone. A large proportion of the remainder is considered dead material and is thrown back as detritus. This is true not only of the quarries here, but of those near Alden. Vast quantities of material now considered useless would be of great value for

ballast and concrete if crushed and properly sized. South of the river considerable stone has been taken out opposite the Purcell quarry, but active operations have ceased some time since.

West of Iowa Falls the Lower Carboniferous rocks are much more rifted and shattered than to the eastward, and the limestone layers become sub-crystalline in texture. The stone takes a good polish, possesses a pleasing color, and if large blocks could be obtained the rock would possess great value for ornamental and structural purposes. Unfortunate it is that the same agency which produced the partially crystalline structure so essential in marbles, was also responsible for the shattering and rifting of the beds. In fact the marbleization was rather a result of the rough usage to which the beds were subjected. The beds continue shattered and sub-crystalline in texture to the point of their disappearance beneath the drift at Alden. Formerly the Ivanhoe Quarry company put in a steam crusher and operated quite extensively near the C., I. & D. tracks on section 16, in Hardin township. Several years ago the building containing the machinery burned down, and the plant has since been dismantled and abandoned.

East of Alden Mr. F. N. Wheeler operates a quarry and has done some systematic prospecting for heavier beds of the sub-crystalline limestone layers. The layers quarried vary from two to five or six inches in thickness, and are of good quality. Efforts to develop thicker layers are as yet unrewarded.

Small quarries at numerous points help to supply local consumption but none are of sufficient importance to merit individual mention.

The Eldora sandstone has been used to a certain extent in the foundations of numerous structures in and about Steamboat Rock, Eldora, and Xenia, but so far as known it is not at present produced in commercial quantities. The stone is extremely variable in texture and state of induration, and these factors taken with its somber color makes it certain

that it will never be popular as a structural material. Vast quantities are available, and when the stone is carefully selected gives good service in the less imposing structures, and its use might be safely and profitably extended in backing walls faced with more expensive materials.

FIG. 36. Eldora sandstone as exposed along the C. I. & D. Ry., near Xenia, Hardin county, Iowa.

The drift affords an assortment of crystalline rocks which are coming into favor in the construction of foundation walls of farm buildings. They are the most enduring of all the structural materials found in the county, and at no distant day they will be prized highly in the foundation work of the more permanent structures.

SOILS.

Hardin is essentially an agricultural county and it is to the productiveness of her fertile soil that her people owe their prosperity and happiness. The products of her quarries and pits are important but the output of her mineral products for

the entire county is scarcely a tithe of the value of the products of the soil from a single township. Barren, untractable or unproductive land is unknown in the county. None of the soil has been formed *in situ* but all is rock meal brought in and deposited by the various ice sheets. It has subsequently been modified by the action of air, wind and water, and has been mixed with more or less organic matter to which its dark color and richness are, in large measure, due. Corresponding to the three drift sheets which comprise the surface deposits of the county, three types of drift soils may be recognized; and along the lower courses of the Iowa and South Fork a fourth type may be designated the alluvium or river-deposited material. The distribution of the loess-Kansan soil is coincident with the loess-Kansan province. It is characteristically a porous, clayey silt, allowing rootlets to penetrate easily and deeply, rich in lime and well drained and ventilated. Its worst properties are a tendency to gully during heavy rains and to bake when dried rapidly. It becomes slightly arenaceous where the loess is very thick on broken grounds, but on the uplands is easily tilled and is very productive.

The Iowan drift soil is confined to the northeast portion of the county,—the region of the Iowan drift plain. It is a rich deep loam, rich in lime, moderately well drained and one of the most productive soils in the county.

The Wisconsin drift soil corresponds to the area occupied by the Wisconsin drift. It has been subjected to weathering agents the shortest time and as a consequence is the least modified. It is, in other words, the least perfect soil. It is rich in available plant food but lacks proper drainage and ventilation. With the introduction of tile drains to carry off the water from inclosed basins and bring about the necessary aeration, the Wisconsin drift soil bids fair to become one of the most productive and lasting of the soils in the county. The percentage of pebbles and bowlders is greater than for any other of the types, but they are not as a rule sufficiently

abundant to hinder cultivation. Alluvial soils are nothing more or less than drift worked over, the finer materials being deposited along the principal streams and constituting the soils of their flood plains. This type is, when not too sandy, very productive and tractable. It is, however, subject to inundation. The type is not important for Hardin county.

ROAD MATERIALS.

This county is richly endowed with large quantities of material suitable for road making, ballast and riprap work. All of the streams of importance which issue from the Wisconsin drift are terraced by extensive deposits of gravels, and the Carboniferous affords an almost inexhaustible supply of material easily available and suitable for all kinds of public road work, and for riprapping and ballasting railway roadbeds. Only the former deposits are at present utilized. The Iowa Central has opened up extensive pits at Gifford on the South Fork, and the Chicago & North-Western Railway company has removed enormous quantities of gravel from the terrace east of the Iowa river, near Gifford. Ten to fifteen feet of gravels are exposed at these points, and, as has already been mentioned, they are post-Wisconsin in age. Water action is apparent, and the beds have been put down at every conceivable angle. The gravels are much coarser above than below. Bowlders of limestone and Eldora sandstone are very abundant.

Save the Ivanhoe quarry the Kinderhook has not been developed for road material. Millions of cubic yards are available for macadam and ballast. Three lines of railway enter Iowa Falls, and a steam crusher used in connection with the quarries to utilize the waste product could not fail to be a good investment if intelligently managed.

SAND.

All of the streams furnish an abundance of sand, either in their terraces or in their channels, suitable for building purposes. Aside from the streams considerable quantities may

be obtained from the kames and sand knobs, which are almost universally distributed over the Wisconsin drift area. Moulders' sand appears at numerous points below the loess in the loess-Kansan area. Near Iowa Falls a very clean white sand is reported, which is believed to be pure enough for the manufacture of common window glass.

WATER SUPPLY.

Only the Iowa river proper furnishes living water throughout the entire year. All of the other streams are entirely dry through seasons of drouth, or are at least reduced to a series of disconnected spring-fed ponds. Notwithstanding the apparent scarcity of surface running water, an abundant supply of good water is, as a rule, easily obtained by means of wells. A decade ago but few wells entirely penetrated the drift, but obtained a sufficient supply for domestic purposes from the interglacial gravels. During recent years the shallow wells have wholly failed during the summer season, or have proved inadequate to supply the increased demand put upon them. The old wells are being deepened, and many of the new wells pass entirely through the glacial deposits and draw their water supply from the sub-glacial gravels or from the indurated rocks of the Lower Carboniferous. Several small artesian basins are known in the county, the most important of which is the basin along South Fork in Buckeye, Ellis and Tipton townships. The wells in this area are located on the flood plain of South Fork and vary from eighty to 120 feet in depth. The aquifer appears to be the sub-glacial gravels, and the water rises some ten feet above the flood plain. Springs are also numerous in this area. The basin appears to be due to the stoppage of a pre-Wisconsin drainage line by the debris of the Altamont moraine.

The deepest well in the county supplies the town of Ackley. The well is 2,030 feet in depth and draws its water from the Jordan sandstone of the Saint Croix. The Ackley well section is incorporated into an earlier part of this report. No

data concerning the pumping capacity or character of the water could be obtained from the town authorities.

The well put down and owned by the city of Iowa Falls struck a flow in the sandy layers which separate the limestone and shale members of the Kinderhook. According to actual tests made for the city, the well has a sustained pumping capacity of more than 10,000 gallons per hour. The water is clear and sparkling, has a temperature of 50° F. and flows over the mouth of the well. A complete chemical and sanitary analysis was made by Prof. J. B. Weems and is appended below:

CHEMICAL ANALYSIS.

	GRAINS PER GALLON.	PARTS PER MILLION.
Silica (SiO_2)	0.83	14.3
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	0.27	4.6
Lime ($Ca\ O$)	8.74	150
Magnesia ($Mg\ O$)	2.43	41.7
Soda (Na_2O)	1.27	21.8
Chlorine (Cl)	0.70	12
Sulphur trioxide ($S\ O_3$)	0.99	16.9
Carbon dioxide ($C\ O_2$)	9.45	162.1
Total	24.68	423.4
Less oxygen replaced by chlorine	0.15	2.7
	24.53	420.7

PROBABLE COMBINATIONS.

Silica ($Si\ O_2$)	0.83	14.3
Alumina (Al_2O_3) and ferric oxide	0.27	4.6
Calcium carbonate ($Ca\ Co_3$)	15.61	267.8
Magnesium carbonate ($Mg\ Co_3$)	4.95	84.9
Sodium sulphate ($Na_2S\ O_4$)	1.50	25.8
Sodium chloride ($Na\ Cl$)	1.16	19.8
Magnesium sulphate ($Mg\ S\ O_4$)	0.21	3.5
Total	24.53	420.7

SANITARY ANALYSIS.

	PARTS PER MILLION.
Ammonia	0.792
Albuminoid ammonia	0.068
Solids on evaporation	446
Solids on ignition	280
Oxygen absorbed in 15 minutes	6 1
Oxygen absorbed in 4 hours	9 1
Nitrogen as nitrites	0.0
Nitrogen as nitrates	0.0

The above analyses show a remarkably low percentage of solids and no trace of nitrites or nitrates, and establish the water as well adapted to both domestic and manufacturing purposes, in fact one of the best potable waters in the state.

The Eldora well is 250 feet in depth, penetrates about ninety feet of drift and sixty feet of coal measures, and reached water in the Kinderhook at a depth of about 180 to 200 feet. The water stands at 135 feet from the surface, which is approximately the level of the water in the Iowa river. The pumping capacity is 50,000 gallons per day.

The railways and the towns of Gifford and Union find an abundant supply of good water in the terrace gravels at a depth of twenty to thirty feet.

Away from the streams modern wells which afford a sufficient supply for stock farms and domestic purposes vary from seventy to 400 feet in depth.

WATER POWER.

The Iowa river is rock-walled and rock-bottomed, and has a high gradient from Alden to Union. A good volume of water flows throughout almost the entire year. As a consequence excellent mill sites are numerous. Mill properties have been located at Alden, Iowa Falls, Eagle City, Hardin City, Steamboat Rock, Eldora, Xenia and Union. All of the above, save the Xenia mill, were more or less actively operated in 1899. A head of from seven to nine feet was readily obtained at all of these points, and from fifty to 100 horse power can be developed during the greater portion of the year. None of the other streams afford more than temporary power for brief seasons during each year, and flood and drouth prove equally fatal to their utilization.

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B. B. Bliss, of Iowa Falls; E. Claud Hecker, of Alden; Superintendent Woodward, of Eldora; and W. W. Rodwell, of Union, for the hearty co-operation and interest in the work. The writer has received the invaluable advice and assistance of the State Geologist, Professor Calvin, and the Assistant State Geologist, H. F. Bain, during the progress of the work. To all who have in any way facilitated the work acknowledgments are gladly given.

THE FOREST FLORA OF HARDIN COUNTY.

BY L. H. PAMMEL.

One of the interesting phases of botany is a study of plants with reference to their adaptation. Plants of widely different relationship are frequently associated in communities. Such plants show the same adaptations as regards theis structures and growth.

Certain physiographic features of the country have a marked influence on the plant communities. Sandy, moist rocks support a very different class of plants from limestone rocks, or the alluvial bottoms of the streams. These features often determine the geographic limitations of some trees. The White pine (*Pinus strobus*) is a very local tree in this state, being confined to the sandstone ledges of eastern and central Iowa. The White pine is not, however, found in this state wherever the sandstone ledges occur. Extensive Carboniferous sandstone deposits occur along the Des Moines from Moingona south, and while the forest growth at various points is somewhat similar to that of Hardin county, three of the prevailing species do not occur, namely, *Pinus strobus* and two birches, the White birch (*Betula papyrifera*), and the Cherry birch (*B. lenta*). Botanists have long recognized that species tend to move northward or southward, and less frequently plants move eastward and westward. The westward extension of the eastern trees in Iowa is marked by certain valleys. Taking the White pine as an illustration its western limits is marked by the Iowa valley. Dr. S. W. Beyer calls

my attention to the report of David Dale Owen,* in which he refers to the occurrence of White pine on the summits of the hills along the Iowa river in Hardin county. Its southern extension is Pine creek in Muscatine county. The Davenport locality Reppert† Watson and Coulter Gray's Manual (6th Ed.) 490 is clearly an error, as I have shown elsewhere. The White birch,‡ *Betula papyrifera*, has its western limit in the same valley, and is clearly more local than the White pine. Macbride§ reports as follows: "Occurs in cultivation, and is reported abundant along the Boone river east. Perhaps comes within the limits of the county in the northeast corner." Its occurrence there would be extremely interesting, since to my knowledge the species does not occur in the vicinity of Webster City along the Boone river. The occurrence of the Cherry birch in the vicinity of Steamboat Rock is another equally interesting discovery. So far as I know this is the only recorded locality in the state. The Cherry birch is a distinctly northern tree, found in moist, sandy, rocky soil in western Wisconsin. The White birch occurs in the more exposed and drier places, conforming to its habitat, in western Wisconsin and northeastern Iowa, as I indicated in a paper in *Garden and Forest*‖ on the forest vegetation of the Upper Mississippi. Macbride,¶ in his paper on the forest trees of Allamakee county, says: "Certainly confined to the northeast corner of the state."

Until finding the species last fall I had not known of its occurrence in Iowa except in the counties north of Dubuque along the Mississippi river.

The flora of this region is a typical northern or, more properly, the transition of C. Hart Merriam.**

The arboreal vegetation is accompanied by many typical northern species. It has many more northern species than

*Rept. Geol. Surv., Wis., Iowa, Minn., 102.
†Iowa Geol. Surv., Vol. IX, p. 387.
‡Plant World, Vol. II, p. 186.
§Iowa Geol. Surv., Vol. IX, p. 152.
‖Vol. IV, p. 400; Iowa Acad. Sci., Vol. I, p. 80.
¶Iowa Geol. Surv., Vol. IV, p. 119.
**Year Book U. S. Dept. of Agri., 1894, p. 209.

Clinton or Dubuque counties and but few of their southern species. *Asimina triloba*, *Carya olivæfornis*, *Cercis canadensis*, and *Q. muhlenbergii* occur at Clinton but are entirely wanting near Steamboat Rock. The typical transition species occur for some four or five miles north of Steamboat Rock but disappear south. These are practically confined to the sandstone ledges. Beyond these ledges the timber presents nothing unusual for central Iowa.

This small area is well watered and where it was not pastured it was decidedly swampy, as evidenced by the profuse growth of *Impatiens fulva* and *Lobelia syphiltica*. The *Cypripendium spectabile* was less common in open places. In the densely shaded woods the ground was covered with a species of *Hypnum*. *Phegopteris Dryopteris*, *P. polypodiodes*, *Asplemium Felix-foemina*, *Polypodium vulgare* and *Aspidium marginale*. The latter to my knowledge has not been recorded for the state, and certainly is much beyond the usual range given to it. In Wildcat Den, Muscatine county, where the physical conditions are somewhat similar, it is entirely absent. The two species of *Phegopteris* have been reported from other sections of the state. All of these are northern species. The small Bush Honeysuckle (*Diervilla trifida*) has a range from Newfoundland to mountains of North Carolina west to Minnesota. Reppert also reports it from Muscatine county. It is, therefore, much beyond its usually given range. The *Cornus circinata* is a common shrub on sandy rocks in western Wisconsin, its natural range being from Nova Scotia to Dakota, south to Virginia and Missouri. Its Missouri occurrence is like the Iowa, usually in isolated places. Reppert records it from Muscatine county along Sweetland creek* and I have observed it as a rare shrub at the ledges in Boone county. The *Cornus asperifolia* is more common. The sandy piny woods are covered with *Danthonia spicata*, which is true also of the woods along Pine creek in Muscatine county and the Carboniferous sandstone ledges in Boone county.

*l. c. 384.

The timber along the Iowa river in former days was much used for railroad ties; the best has, however, long since been removed. There is, however, still some merchantable timber which is being cut into lumber, and much is used for fuel. Of the *Betula lenta* there were trees twelve inches in diameter which might very profitably be used for lumber.

The forests have been much injured; there is, in fact, general complaint that the forests do not do as well as formerly. Several causes have led to this. The unseasonable winter of 1898–1899 killed many trees or injured them so severely that they will never recover, and should at once be cut out. Trees varying from saplings to those one and a half and two feet were destroyed by this freeze. Some of these trees have attained an age of fifty to seventy-five years. Is it possible that during all these years Iowa has not experienced such a winter? Where there are solid bodies of large trees still standing it is reasonable to suppose that the conditions during the past season were unusual, or man has so modified present conditions that trees have been unable to resist unseasonable climatic conditions. In going through these forests one cannot help but notice that man is responsible. I passed through acres of timber in which the ground had scarcely a weed growing,—the ground was bare. It had been stocked to such an extent that there was no longer any covering or protection to the roots. The farmer in Hardin county and elsewhere in the state, is attempting to grow two crops on the same ground at the same time. The first principle in forestry has not been learned. It is evident that unless the farmers adopt a different system of treating the forest they must, sooner or later, lose what little timber is remaining. There are many points along the Iowa river, in Hardin county, that can never be utilized for farming purposes, which should be devoted to forestry.

LIST OF TREES.

TILIACEÆ.

Tilia americana L. Common in narrow valleys and hillsides along the Iowa river.

SAPINDACEÆ.

Acer saccharum Marsh. What I take to be this species occurs along the Iowa river.

A. nigrum Michx. This is the most common maple in central Iowa along the Iowa river. Large trees a foot to one and a half feet in diameter.

A. saccharinum L. (*A. dasycarpum* Ehrh.). The Silver maple or Soft maple is the most abundant of the maples; grows in alluvial bottoms of the Iowa river, frequently attaining large size. The species is much used for fuel. Also frequently planted as an ornamental tree.

Negundo aceroides Moench. The Box elder or Ash-leaved maple is abundant in low, rich grounds.

LEGUMINOSÆ.

Robinia pseudacacia L. Naturalized at several points in the county.

Gymnocladus canadensis Lam. In bottoms of Iowa river; frequent.

Gleditschia triacanthos L. Frequent in bottoms along the Iowa river.

ROSACEÆ.

Prunus americana Marshall. Frequent not only along the Iowa river, but along all the smaller streams.

P. virginiana L. The Choke cherry is common in woods throughout the county.

P. serotina Ehrh. Frequent in woods throughout the county.

P. pennsylvaniaica L. In upland woods is frequent.

Pyrus iowensis Wood. Common, forming thickets, second bottoms and uplands.

Cratægus coccinea L. In bottoms common.

C. mollis Scheele. The most common species in second bottoms along all of the streams, forming thickets.

C. punctata Jacq. In bottoms.

C. tomentosa L. In upland woods.

Amelanchier canadensis Torr & Gray. The species occur not only upon the sandstone ledges, but in woods throughout the county.

CORNACEÆ.

Cornus alternifolia L. Common in sandstone ledges and in sandy second bottoms of woods. The following additional species occur, but none become trees: *C. sericia* Michx., *C. asperifolia* Michx., and *C. paniculata* L'Her.

OLEACÆ.

Fraxinus americana L. Common in low, wet places along the Iowa river.

F. viridis Michx. The most common ash in the region.

URTRICACÆ.

Ulmus fulva Michx. The Slippery elm is abundant in all upland woods, and forms one of the chief characteristics of the woods. A valuable species for lumber and posts.

U. americana L. The American or White elm is common in woods along the alluvial flood plains of the river. Here the species attains its greatest size. Many of the most valuable of these trees have been cut. The species also grows along all the tributaries of the Iowa river throughout the county.

U. racemosa Thomas. The Cork elm probably also occurs but the writer did not observe the species.

Celtis occidentalis L. The Hackberry is common in the flood plains of the Iowa river. The trees are of medium size.

Maclura aurantiaca Nutt. The Osage orange was much used for hedges, but the trying winter of 1898–1899 killed nearly all of the plants in the county.

Morus rubra L. The Red mulberry was not observed, although it occurs farther south along the Iowa river.

PLATANACEÆ.

Platanus occidentalis L. The Sycamore occurs along the Iowa between Steamboat Rock and Marshalltown, but was not observed in the immediate vicinity of Steamboat Rock.

JUGLANDACEÆ.

Juglans cinerea L. Common throughout the county in upland woods.

J. nigra L. Common in flood plains of Iowa river and its tributaries.

Carya alba Nutt. Common in upland woods.

C. amara Nutt. Common in moist soil, especially ravines an d moist hills.

CUPULIFERÆ.

Betula lenta L. Some large trees one foot in diameter occur in the moist woods below the sandstone ledges. Much of the birch has been removed. This is very valuable wood and is much used by cabinet makers. Its occurrence in central Iowa is quite unusual.

B. papyrifera Marshall. The Paper or Canoe birch occurs on the upper exposed sandstone ledges. The bark of the trees is white and splits into paper-like layers. None of the trees remaining would make merchantable timber. Its occurrence in central Iowa is quite unusual.

Betula nigra L. Iowa river bottoms.

Ostrya virginica Willd. Slopes of hills; common.

Carpinus caroliniana Walter. The Hornbean is less common than the Ostrya. It occurs in similar situations; like hop-hornbean it produces an exceedingly tough wood.

Quercus alba L. Fine bodies of White oak once occurred on the beach lands of the Iowa river, but this has long since been removed. The second growth is not coming on rapidly because of the injudicious pasturing.

Q. macrocarpa Walt. The Bur oak occurs rather commonly on the bench lands and in bottoms.

Q. rubra L. The Red oak is the most common oak of the region. The old timber has been pretty well culled out.

Q. tinctoria Bartram. The Black oak occurs in gravelly or somewhat sandy soil along the Iowa river.

SALICACEÆ.

Salix nigra Marsh. The Black willow is common along the Iowa river.

S. amygdaloides Anders. Along the Iowa river.

S. alba L. Commonly cultivated for wind-breaks and hedges.

S. rostrata Richardson. Common in moist meadows and banks along streams.

Populus alba L. Widely introduced as a cultivated plant and a frequent escape.

P. tremuloides Michx. The Trembling aspen is not infrequent, forming small groves.

P. grandidentata Michx. Occurs in rich woods along the Iowa river, especially with the White pine and birch.

P. monilifera Ait. Common everywhere in bottoms along the Iowa river and the smaller tributaries.

CONIFERÆ.

Pinus strobus L. The White pine occurs for several miles along the Iowa river near Steamboat Rock and along the smaller creeks. This is the most western locality in the state.* The most southern locality in the state is Muscatine. It is more frequent in northwestern Iowa.

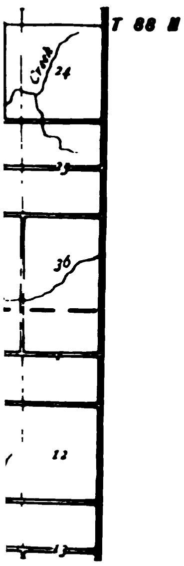
Juniperus virginiana L. The Red cedar is not common, but occurs on the hills along the Iowa river about Steamboat Rock. The trailing shrub *J. communis* also occurs below Steamboat Rock on the damp hillsides.

*Plant World, 2:186. Contr. Bot. Dept. Ia. St. Coll. Agr. and Mech. Arts 14.

GEOLOGY OF WORTH COUNTY.

BY

IRA ABRAHAM WILLIAMS.



BY

S. W. BEYER

1900.

Scale $\frac{1}{125,000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

GEOLOGY OF WORTH COUNTY.

BY IRA A. WILLIAMS.

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INTRODUCTION.

SITUATION AND AREA.

Worth is included in the northern tier of Iowa counties, and accordingly lies next to Minnesota along its northern border. It has Winnebago on the west and Mitchell on the east, while Cerro Gordo lies next to the south. In common with the other Minnesota border counties, Worth county has a row of fractional townships along the northern line. In comparison with the average county of Iowa it is unusually small in size, possessing only twelve townships, while each member of the northern row of these lacks more than a mile of having its full north-south dimension of six miles. With the deficiency in area above mentioned, Worth county contains approximately 400 square miles, about 256,112 acres.

PREVIOUS GEOLOGICAL WORK.

In the records of early geological observations in Iowa very little has been written directly concerning the region under consideration. Pioneer explorers found subjects of only passing interest in the broad expanse of grassy prairies, here and there modified by rows of prominent hills and knobs, and not yet obscured by the numerous artificial groves with which they are now so copiously dotted. To the early scientist Worth county presented few geological phenomena to attract more than momentary attention on account of the almost universal drift covering, and hence merited the expenditure of little space in the several reports that have been made on northern Iowa geology.

David Dale Owen,* in his report on the geology of Wisconsin, Iowa and Minnesota in 1852, makes bare mention of the Devonian rocks exposed along the banks of Shell Rock river, as also of the fact of their being quite generally buried beneath the drift.

In 1858 A. H. Worthen,† under the direction of Prof. James Hall, first state geologist of Iowa, traversed the area drained by the Cedar river and its branches and referred the country rock of Worth and Cerro Gordo counties to the Hamilton group.

In the final report of Dr. C. A. White,‡ 1870, are recorded the most detailed observations yet published. In his discussion of the geology of Worth and Cerro Gordo counties, the extreme thinness of the drift along Shell Rock river is spoken of and comment made on the remarkable difference in surface features between the eastern and western portions of the county. The rock exposed along the Shell Rock was referred to the Devonian; but the magnesian layer was not recognized in Worth county. Several analyses of peat taken in the vicinities of Northwood and Silver Lake were made, and the results were included on page 398 of the same volume.

The terminal Wisconsin moraine (now known as the Altamont) was traced across the county by Upham§ and in his report on "the terminal moraine in Iowa," published in 1880, its course is accurately described. Further study of the surface will, however, necessitate some rectification of the position of the ice margin as mapped by Upham.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface of Worth county presents two extremes of topographical development; one, the area covered by the hills and ponds of the Altamont moraine, the other, the mild drift plain

*Owen's Geol. Survey of Wisconsin, Iowa and Minnesota, p. 78.
†Geology of Iowa, Vol. I, Part 1, p. 306.
‡Geology of Iowa, Vol. II, pp. 249-251.
§Ninth An. Rep. Minn. Geol. & Nat. Hist. Surv., p. 389, 1880.

of the Iowan stage. The former occupies essentially the western half of the county, while over the eastern half the Iowan drift predominates. A line separating these two areas or, in other words, in a general way tracing the edge of the Wisconsin drift, would enter from the north, between six and seven miles east of the middle, and, continuing across the county in a general southwest trend, pass into Cerro Gordo an equal distance west of the middle point of the south county line. The sudden break from rugged to mild surface features is very noticeable to the traveler going from west to east across the county. Marked differences are apparent in the condition of the streams, as to both the present stage of development of the systems and the history and age of the separate streams. In accordance with the relative ages of the two till sheets, the drainage is less perfect in the newer Wisconsin than on the older Iowan.

WISCONSIN DRIFT AREA.

So recent in geological time was the recession of the Wisconsin, the last ice sheet which infringed upon any portion of Iowa's territory, that the consequent streams thus originated have had a very insufficient length of time in which to subdue their genetic relatives, the lakes, ponds and marshes. Evidence of the youth of these streams is found in the scarcity of side branches, the high gradient, and their indefinite courses among the hills. In this category would be included Beaver and Winan creeks in Fertile township, Goose creek flowing across the northeast corner of Hartland, the two branches of Elk creek in Bristol township, as well as numerous other small tributaries not of sufficient importance to merit a name.

Those rivers of sufficient size to remove the material as rapidly as it was furnished by the melting ice succeeded in maintaining their old channels entirely or in part. Among the rivers of Worth county Shell Rock is the only one that has retained its pre-Wisconsin course entire. The upper part

of the old Elk creek valley is filled in and practically obliterated so far as its relation to the present Elk creek is concerned. It is quite plain that Lime creek, at some stage during the presence of the Wisconsin glacier, was diverted from a portion of the channel occupied by it previous to the advent of that ice.

By inspection the region of Wisconsin drift may be divided into two areas, the division being based upon the prominence of development of morainal features. Including nearly the northwest one-half of Northwood township, the outer morainal region would embrace the whole of Hartland and Brookfield townships and a generous three-eighths of Danville in triangular shape off the northwest corner. Although typically morainic the pronounced topographical characters are not here exhibited on so large a scale as they are on the inner morainal tract to the west. Warren Upham, in "Exploration of the moraine in Iowa,"* gives the following accurate description:

"In Worth county the eastern belt of this moraine enters Iowa in sections 8 and 9, Northwood, and extends four miles southwest with a width of about one and one-half miles, to section 24, Hartland, and then three miles south to the northeast corner of Brookfield. It consists of uneven swells and hills thirty to forty feet above the intervening hollows, and fifty feet above Northwood, which is situated one and one-half miles southeast, on a plain of valley drift about twenty feet above the Shell Rock river. Next this belt appears to be broken and removed by an offset six miles to the west; and thence its course is south through the east part of Bristol, and through sections 2, 11, 14, 23, 27 and 33, Fertile, its southeast border being about one-third mile northwest of Rhodes' Mill, in section 34. In these townships the formation is in knolls, hillocks and short ridges, trending to the south or southwest, and thirty to sixty feet high."

*Ninth Ann. Rep. Minn. Geol. and Nat. Hist. Survey, p. 889.

It will be noted that after reaching the northern edge of Brookfield the moraine is spoken of as removed by an offset six miles to the west. If traced southward the extreme margin would lead along the eastern edge of Brookfield and across Danville, as before outlined. What is here spoken of as an offset to the west is apparently an opening in the Altamont moraine, exposing an inner moraine here six miles west of the Altamont, and marking an extended halt in the ice retreat. This inner moraine is well defined southward through Bristol and into Fertile township, where it unites and coincides with the outer range of hills which here assumes a more southwesterly direction. Again, from Mr. Upham's report:

"At the southwest corner of this county these morainic hills become more abundant and abrupt, and form a very rough wooded belt two or three miles wide, for a distance of six miles west from Rhode's Mills to Pilot mound. This tract includes parts of four counties, and is bounded on the south by Lime creek."

This row of hills may be followed northward into southern Silver Lake township where its prominence is less marked, but where it nevertheless maintains its strictly marginal characteristics. Its individuality is somewhat obscured by a merging into the maze of hills and peaks with which the whole area of Hartland and eastern Silver Lake is well supplied.

Viewed broadly, it would appear that the Wisconsin ice invasion of Worth county consisted of a lobular ice border, with, perhaps, many local advances and retreats. How long a time, or how numerous the minor oscillations, are matters of conjecture only.

It is obvious that the region most recently deserted by the ice would present the most youthful characteristics. The region of lakes, including Silver, Bright and Rice lakes, is bounded on the east by the range of hills, the inner moraine. Silver lake seems to have been caught immediately within this confining wall. Rice and Bright, while not so near

the edge, are the direct results of this temporary halt in the ice motion. During the final period when the ice prevailed over the three western townships, Silver Lake, Bristol and Fertile, those previously occupied, Hartland, Brookfield and portions of Northwood and Danville, were divested of their frigid mantle and probably overrun with water, laden with debris from the thawing glacier's edge. The retreat of the ice west-northwestward was more or less continuous, with minor intermittent pauses, to the position of the Altamont moraine proper in Winnebago county, which culminates at the southern border of the county in Pilot Mound, a heap of glacial detritus more than 180 feet high.

The topographical disparity between these two areas of Wisconsin drift is one of degree of development only. So far as the difference in time since their deposition is concerned, geologically it is not of sufficient length to be taken into account in a consideration of subsequent denudation of the land. What is observed on the one is found much exaggerated in the other. The face of the country in general is one of ice moulding rather than water sculpture.

The presence of knobby, rounded hills unaffected by water erosion, and ponds and kettle holes situated at high elevations and in apparently most unstable positions are conspicuous features over the whole morainal area. In Northwood township these forms predominate, though subdued, the most prominent points reaching elevations of from twenty to twenty-five feet above the level of the adjoining Iowan drift plain. In Hartland they assume greater proportions, reaching heights of thirty to forty feet. South into Brookfield they extend in elongated ridges, but diminishing in size. At the eastern edge of Brookfield, in the old valley of Elk creek, now occupied by that stream, are developed some of the most unique morainal features in the county. The scale of the ice architect was small in fashioning these heaps of debris, but here is displayed, in miniature, what elsewhere in the county appears with greater magnitude. Some of the forms

observed are nicely rounded kame-like knolls, not more than thirty feet high, and apparently of not more than twice this distance in basal diameter, with surfaces strewn with small bowlders; some are more elongated and of the nature of the esker, while others, locally known as "hog's-backs,"

FIG 37. Morainal knobs in eastern Brookfield township, in the old valley of Elk creek. The bowlders are almost exclusively limestone.

are distinctly drumloid in character. The broad preglacial valley of Elk creek appears to have been a convenient place for the eastward extension of a narrow tongue of ice, which modeled and built these conspicuous land forms at its leisure, sometime after the main body had receded. In its course across Danville this marginal tract is not specially pronounced, the rolling, hilly country giving way to the mild surface of Iowan drift.

At the offset to the west in Brookfield township, mentioned by Upham, the immense ridge of drift which extends north and south between Bristol and Brookfield into Fertile township is a very conspicuous topographical feature. Approached from either the east or the west it rises before the traveler

until at the summit, at an elevation of about 130 feet, he overlooks wide stretches of county in both these directions. Southward it eventually blends into the miscellaneously arranged mass of hills in the southwest corner of the county. Lime creek breaks through this morainal belt at Fertile and for more than two miles east along nearly the remainder of its course in the county it is bounded on the south by high bluffs of Wisconsin drift. This is only another instance illustrating the lobular, irregular nature of the ice border. The region west of Fertile, which is part of a larger area extending into Cerro Gordo, Hancock and Winnebago, and which reaches its climax in Pilot Mound at the northern border of Hancock county, presents perhaps the most typically developed ice-moulding in the county. Here are exhibited with striking prominence hills and eminences, some rounded and steep, others elongated with steep sides, and showing flattened tops. Some are connected in series assuming a general north and south direction, while others are isolated in position and often surrounded by low wet ground or even a pond or peat bog. These latter, with occasionally a small stream, are the only variations in the monotony of hill and hollow, and the public highway must often diverge a mile or more from its proper location in order to avoid swamps and miry places. Natural conditions, assisted by the agency of man, are at work draining these places, for within the space of the last twenty years areas now passable and even under cultivation were covered with water during spring and early summer, and so wet as to be quite unfit even for pasturage the remainder of the year.

In the western part of Bristol and Silver Lake townships there is a general slope to the west. The surface features are prominent, but not so characteristic as to the east and south.

Rice lake, so called from its supporting a luxuriant growth of wild rice around its marshy borders, is so situated as to lie mostly in Winnebago county, only an elongated tongue-like projection extending into Bristol township of Worth

county. Of the approximate two hundred acres within Worth county no portion may be said to be covered with water the year round. It has an average width of one-fourth mile, but rapidly widens to more than one-half mile where it crosses into Winnebago county. The basin occupied by the lake embraces an area considerably larger than that actually inundated. The major portion of the large depression is overspread with a heavy accumulation of peat, which sustains growths of rushes, wild rice and other water-plant life. At no point in the water-covered portion is the depth more than a few feet, as a thin reedy vegetation is always present in the most open places. It is surrounded by low hills of drift, which appear to have been modified but little since they were deposited by the ice. They often barely separate from the main depression other depressions in the drift surface which lack entirely the first vestige of drainage. This would indicate that the origin of Rice lake is the same as its kettle hole relatives. From such a hollow there would be no outlet for water except through evaporation and seepage. The comparative mildness of the topography to the south may be illustrated by the fact that an attempt was recently made to drain the lake in that direction by ditching and tiling.

Silver lake, somewhat north and east of the center of Silver Lake township, is a small body of open water confined within walls of glacial drift. It is nearly a mile long and one-half as wide. It has no outlet. In periods of excessive precipitation its overflow is discharged through a small stream with only a poorly defined channel northeastward across the line into one of its genetic relatives in Minnesota. To the west and east the lake extends out to a swamp covered with rushes and swamp grass. To the north and south where the open water is immediately bounded by banks of till, conspicuous levees have formed through the action of the ice pressing shoreward. There are no inlets of any importance. A few V-shaped ravines, originating only a short distance from the shore among the hills, have served to enlarge but slightly the

catchment area as it was left at the final retreat of the ice. A conception of the limited extent of this area may be gained from the fact that numerous ponds containing water are found only a few rods from the edge of the lake itself. A notable example of this kind is presented at the south edge of the lake, along which the wagon road passes. The road here follows for some distance along the crest of a ridge, "hog's-back," of drift fifteen to twenty feet above the water. This acts as a partition between a peat swamp to the south and the open water of the lake.

Bright lake, near the northwest corner of Silver Lake township, and hence, near the northwest corner of the county, is another small lake of glacial origin. It is surrounded by the knolls and rounded hills of the Altamont moraine. Within these it is entirely enclosed, with the exception that an attempt has been made to produce artificial drainage to the northwest. Local surface drainage is the chief source of the water supply. Except in seasons of unusual rainfall, no outlet is necessary. The amount of evaporation is sufficient to maintain an equilibrium, and even in exceptionally dry periods to produce complete desiccation, so that portions of the area included in the lake basin are almost yearly under cultivation.

Deserted lake basins are not infrequently found. In Fertile township, less than a mile north of the town of Fertile, is an old lake bottom now covered with a thick layer of peat. It includes the west central portion of section 26, practically the north half of section 27, and triangular areas off the corners of 21, 22 and 28. It is not beyond the remembrance of the old settlers of the neighborhood, that this basin known as "Goose lake," was perennially covered with water. This broad flat is now mantled with a thick growth of marsh grass, and although not yet sufficiently subdued to admit of cultivation, pasturage and the natural filling in from the surrounding hillsides are rapidly converting the springy, miry peat soil into one of a more firm and stable character, suitable for purposes of agriculture.

The material of these deposits as shown in a road cut across Goose lake is light brown in color near the top, grading downwards through different shades of brown to nearly black at a depth of four or five feet. In the upper portion the moss fibers are distinct, forming a closely interwoven spongy mass, while a few feet below, where the plant fibers are somewhat altered, a more compact earthy aspect is presented.

IOWAN DRIFT PLAINS.

That part of the county lying east of the Wisconsin drift margin, as described in the early part of this paper, belongs to the region of Iowan drift. This till sheet was deposited over all northeastern Iowa, with the exception of the "Driftless Area" in the northeast corner, and presumably it underlies the later deposits of Wisconsin drift which cover the western part of Worth county. Owing to its thinness and the lack of a distinct morainal margin, its southern border has not yet been worked out in detail, but, in a general way, the limit would be a line taking a southeasterly direction from a point in southern Hardin county, where it appears from under the Wisconsin, through Marshall, central Tama, Benton, northern Johnson, Cedar and Scott to the Mississippi river. As the order of superposition determines the relative age of deposits, it will be obvious that the time of deposition of the Iowan drift must ante-date the deposition of the Wisconsin. This is, however, not the only test to be applied in determining the matter of relative age. The person of only ordinary habits of observation cannot but be impressed with the more mature aspect presented by the broad level plains and gentle swells of eastern Worth as compared with the hummocky undrained surface configuration of the western portion of the same county. The one presents some of the characteristics of an erosional topography while the other is a geologically young and ice-moulded topography.

The characteristic features of this till sheet as displayed here, are very similar to those elsewhere studied and described. Although universally overlain with Iowan drift, the

present greater inequalities of the surface are not entirely due to the material of this drift sheet. In fact it would seem that nearly if not quite all of the prominent variations in relief are the expressions of a pre-existing surface of water erosion. Over the major portion of the area this undoubtedly depends directly upon the land forms of the next older drift sheet, the Kansan, so called from its having reached its maximum southern extension in Kansas. But along the streams, and the Shell Rock in particular, the country rock determines largely the land contour. At several outcroppings of the indurated rocks along the lower Shell Rock, except for the prevalence of bowlders, the presence of any glacial drift whatever would scarcely be recognizable.

From the contact line with the Wisconsin in Northwood township a typical level drift plain widens out to the south and east: Northwood is situated on this plain between twenty and thirty feet above water in Shell Rock river. So extremely flat is the region, and from lack of gradient so little chance have the erosive agents had to do effective work, that drainage is almost entirely wanting. As a consequence the rain-waters accumulate in the slightest depressions, where they either evaporate or disappear through seepage. This state of affairs so close to the edge of the Wisconsin drift may in some measure be due to clogging up of drainage ways by the over-wash material from this drift sheet; or as is the case in other parts of the county, the lack of drainage appears to be due to the original level condition of the drift surface.

Eastern Worth in general is a series of these plains with a gradual slope to the south and east. The greater portion of Barton township, with eastern Kensett, is, with the exception of occasional mild undulations, a broad, level expanse stretching southward so as to embrace also the northern third of Union. Over parts of this area, in Barton township north of Bolan, in exceptionally wet springs, square miles have been known to remain practically under water for some days. So slight is the relief and so low the gradient, the water appar-

ently hesitated in doubt whether to seek egress through Deer creek to the northeast or Shell Rock to the southwest.

Another striking surface irregularity that is encountered at times, quite frequently in Union township, is the presence of what appear to be at first sight kettle holes of glacial origin. These are usually more or less circular in form, often filled with water, and present generally the characteristics of the glacial pond. They vary from three to ten rods in diameter and from three to six or eight feet in depth, while sometimes two or three may be connected by a narrow channel-like depression. Cultivation of the land has done much towards obliterating many of these, but considering their position on this relatively old drift sheet, as also the proximity to the surface of the limestone underlying this region, a possible explanation may be found in a process more characteristic of a limestone region than that of ice moulding. Wells in the country east of Shell Rock river indicate distances to rock of from three to forty feet. Where the limestone is so near the surface, and covered only with a thin layer of pervious drift material, percolating waters would have a very solvent effect upon the limestone thus exposed to their action. Should the water on reaching the rock surface chance to find a crack or fissure it would, on account of the solubility of the rock substance, begin at once to enlarge the opening, and eventually find its way out through subterranean passages. With the process once started, allow it to operate for ages, and there will be formed an inlet to a subterranean stream with gradually increasing proportions as the processes of disintegration, solution and transportation continue. Environment in general goes to indicate that these "sink holes,"* as they have been designated, have formed through this process. Clogging up of an underground water way would evidently, by further accumulation, result in a pond which would resemble in many respects the kettle hole of a new ice topography.

*Rocks, Rock Weathering and Soils, G. P. Merrill, p. 259.

That portion of Deer Creek township, north of Deer creek, which divides the township diagonally from northwest to southeast, takes on a more rugged aspect, which character persists eastward into Mitchell county. This, as also the more dissected area in southern Union township, seems to be in part the results of a more vigorous water action. Although streams of any importance are scarce, what few small drainage ways are present have eroded their channels, in most cases, to the rock surface. Though all have had an equal length of time in which to accomplish this erosion, it is evident that those passing through regions of comparatively thick drift covering will cut more rapidly into this loose superficial material than those which encounter the indurated rock strata at a depth of only a few feet. The deeply eroded stream channels correspond in a general way with areas of thick drift and hence produce the rougher topography.

DRAINAGE.

In harmony with the two types of land surface represented in the county are the drainage systems developed. In efficiency of drainage a similar comparison may be made as between the youthful and more mature drift surfaces. Not only is complete drainage a sign of an old topography, but a mature land surface is to a great extent the result of the work of water as an erosive agent. The Iowan drift is, therefore, more nearly perfectly drained than the newer Wisconsin, although the river systems, as ordinarily considered, lack much of typical development, even on the older drift sheet. Shell Rock river, Elk creek, its largest confluent, and Lime creek, the three largest and most important streams of the county, all flow in preglacial valleys in parts of their entire courses.

*Lime creek**—True to its name, that portion of Lime creek included within the boundaries of Worth county, flows over a limestone bed, and its channel is usually limited by walls of this same material. Could the person who named it have observed it at the beginning of the last ice invasion, or even

*Iowa Geological Survey, Vol. VII, p. 136.

before the advent of the Iowan ice, he might have as appropriately assigned to it this appellation, for it occupies a well defined preglacial valley, bounded by rock-supported terraces.

Pursuing a general northerly direction after its random windings among the knobs and hills of western Cerro Gordo county, it enters Fertile township near the middle of section 34. Continuing northward for a little more than one-half mile to the town of Fertile, it makes a bold turn of nearly 90° to slightly south of east, which general trend it maintains to the east edge of Fertile township, where it comes to the south county line. Eastward along southern Danville it meanders, as though reluctant to depart, and crosses the county line seven times within a distance of one and one-half miles before making its final exit into Cerro Gordo at the middle point of the southern boundary of section 32.

Below Fertile the creek skirts the eastern bluffs which bound its valley, here nearly one-fourth mile wide and narrowing southward. The confining hills range from twenty to thirty-five feet in height. The valley floor is strewn to the water's edge with drift material which often stands out in low ridges or mounds. Bowlders are plenteously scattered over the surface of the drift. The stream has here cut a maximum depth of six to eight feet into the limestone, which depth gradually lessens southward until at the south county line the dip of the strata carries them beneath the level of its bed. In changing its trend towards the east or southeast it assumes the normal direction for the strike streams of northern Iowa. Lime creek, at the point where the direction of its course becomes normal, passes into the region of Iowan drift, and at once a series of terraces, of which two are especially prominent, appears. These terraces are mainly developed on the north side of the stream. On the south are high bluffs of Wisconsin drift as far as the middle of section 31 of Danville township, where less pronounced hills of Iowan take their place. The stream holds quite closely to the southern border of its ancient valley along the whole of its eastward course.

In fact, at no point was there observed any terrace development to the south. This may in part be accounted for from the fact that Lime creek is a strike stream, one that runs parallel to the strike, and consequently at right angles to the dip of the underlying sedimentary rock strata. The dip being to the southwest, the gravitational tendency of the stream in corrading its channel would be to work gradually in that direction. Another factor which might come in to accentuate this process is the relative rapidity of weathering in the two walls of the valley. The north wall, exposed to the direct rays of the sun during the day, is thus subjected to the greatest daily extremes of temperature. The same differences will hold with respect to the seasonal variations. The rock ledges, following the physical law that heat expands bodies and cold contracts, would absorb heat during the warm parts of the year, and at the same time take in considerable moisture. As the temperature is lowered during fall and winter, the stored up heat is given off, and the contraction alone would be sufficient to accomplish much in rending the rock mass by cracking and fissuring. But here enters as an effective aid to the contraction of the rock mass the expansion of the included moisture on a lowering of temperature. Water is an exception to the above mentioned law of contraction and expansion, as is well known by the phenomenon of freezing. The small particles of moisture held in the interstices and cavities of the rock upon freezing exert perhaps a greater force in rock-breaking than any other agent. Thus are the processes of insolation and expansion, cooling and contraction, united and at work upon all rocks wherever such conditions exist. It is obvious that although the same conditions would obtain in the south wall of the valley of Lime creek, the extremes of temperature would not be so great, owing to the oblique angle at which the rays of the sun would strike it, if at all. Other active influences would be weakened in proportion. Therefore, it is not unreasonable to conclude that these secularly operating agents have been instrumental

in bringing about the state of affairs that to-day exists in the valley of Lime creek.

The history of the stream, which has been recorded in full by Dr. Calvin in his report on the geology of Cerro Gordo county,* would hold good for that portion of it that traverses Worth county territory, for it both enters from, and makes its exit into Cerro Gordo. South of Fertile and before making the bend to the east, Lime creek has evidently done considerable work towards making a valley for itself, the greater portion of which was excavated during the latter part of the Wisconsin ice epoch. It is not an alluvial valley, but one partly drift filled and sprinkled with bowlders. Some time during this stage of glaciation, and evidence at hand would point to an early stage, Lime creek was diverted from its preglacial valley at Fertile where the abrupt change in direction has already been noted. Had this diversion taken place late during the sojourn of the Wisconsin ice, the stream in this morainal region would not have the width of valley which it exhibits to-day; for the subsequent lapse of time has not been sufficient. Further, in the history of any stream, valley making does not proceed to any extent without a consequent deposition of alluvial material, but there is here no alluvium; the peculiar conditions of low bowldery mounds and ridges extend in this part of the valley to the very margin of the channel. It is probable that a late ice advance has strewn the alluvial valley, cut during early Wisconsin times, with drift detritus, thus making clear the present somewhat anomalous state of affairs.

In its course eastward this stream skirts the northern edge of a lobular eastward extension of Wisconsin drift which it is reasonable to suppose may have narrowed the old Lime creek valley more or less by a process of filling in which gradually pushed the stream northward. Lime creek has cut a maximum depth of twelve feet into the limestone since the retreat of the Iowan glaciers which spread a thin sheet of till over hill and hollow of probably the entire county. From the immediate

*Ann. Rep. Iowa Geol. Surv., Vol. VII, p. 187.

bank of the stream extending back with a gentle ascent sometimes one-half mile or more, but usually only a few rods, is a low plain covered with a thin layer of Iowan drift and strewn with conspicuous Iowan bowlders. This is bounded to the north by a sudden rise of twenty to thirty feet which initiates a broad terrace plain, also sloping slightly toward the stream, and stretching away to the north often more than two miles, where it is again bounded by a well defined ascent of twenty to twenty-five feet. Beyond this hills of Iowan drift assume the role of surface deposit and thus bound Lime creek's ancient valley. On the level of the second terrace, broad swales extend northwestward, with very gentle inclination, even to the edge of the Wisconsin drift. These are occupied by stream channels that are dry most of the year and which originate in some peat marsh or pond on the edge of the morainal area. Such an instance is noted with its beginning in section 21 and including portions of 22 and 27 of Danville township, also one originating in section 20 and embracing part of 29 of the same township. These appear to have served as broad waterways accommodating sluggish flows from the edge of the melting ice.

The history of the stream cannot be more clearly stated than by inserting a quotation from Professor Calvin:*

"The preglacial valley had a width reaching from the south bank of the present stream to the line of hills which form the northern border of the second plain noted above. The sub-Aftonian, if it was ever deposited in this region, cannot be differentiated from the Kansan, but it is certain that, at the close of the Kansan stage, the old valley was only partially filled with detritus, and an important drainage stream of the subsequent interglacial stage followed the old depression and in part re-excavated the old valley. At the beginning of the Iowan stage the re-excavation was far from complete, its amount being represented by the space between the south wall of the valley and the first terrace north of the present

*Iowa Geological Survey, Vol. VII, pp. 187-8.

stream. The Iowan glaciers deposited only a very thin sheet of drift over this region; but they carried numerous bowlders that are scattered over the whole surface of highlands and lower plains. The plain between the terrace and the channel, and rising only a few feet above the level of the water, is

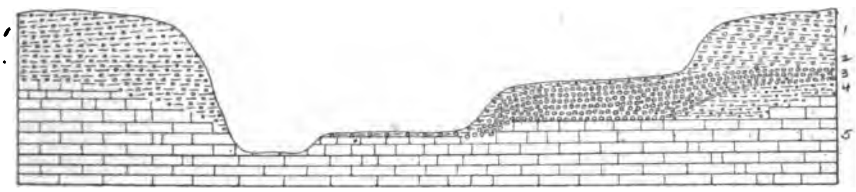


FIG. 38. Profile across the valley of Lime Creek in western Danville township. 1. Wisconsin drift. 2. A thin layer of Iowan drift which overlies both terraces. 3 Buchanan gravel. 4. Kansan till. 5. Cedar Valley limestone.

thickly strewn with large Iowan bowlders that have not been disturbed since they were deposited at the level at which they now lie. The present channel is a shallow trough cut in the Iowan drift of this lower plain and represents the inconsiderable amount of erosion since the withdrawal of the Iowan ice."

At the edge of the moraine in the region of Fertile these terraces gradually lose their identity, although the widely excavated ancient valley may be traced in a continuous northwest direction nearly to Winnebago county. It is quite disguised in places by the hills and ridges of the drift which partly fill it, while at other points its limits are still very evident. In general, this preglacial valley appears as a broad depression, which the Wisconsin glacier failed to obscure in dumping its load of rock detritus. Beaver creek, a small postglacial stream, flows through this partly filled trough. Originating among the hills and ill-drained ponds of Winnebago county, it joins Lime creek at Fertile. Although it effects the drainage of that portion of western Fertile which is drained at all, so meagrely is this developed that the catchment area would scarcely exceed the width of the depression that marks the old Lime creek valley. The stream has accomplished some down-cutting, but it has not eroded the entire valley which it occupies. Its bed in many places seems

to be made almost entirely of the smaller rock fragments of the Wisconsin drift. Just at the point where it joins the present Lime creek valley is found a rather anomalous collection of larger bowlders resembling much those characteristic of the Iowan till sheet. Veined and crumpled gneisses, granites and greenstones are here clustered together in a manner not at all characteristic of the newer drift; they probably have been derived from a remnant of the older Iowan.

Lime creek receives two small tributaries—Winan creek at the southwest corner of Danville township, and Willow creek at the point where it leaves the county at the south edge of section 32.

Winan creek has its source in the neighborhood of Rice lake, Bristol township, in the swales and ponds of the moraine. Meandering diagonally across Fertile, it escapes upon the Iowan drift practically as it reaches the upper terrace of Lime creek valley in section 25. Rock is not exposed in its banks, but after leaving the Altamont moraine it flows at about the rock level in the upper terrace of Lime creek. Except an occasional ill defined slough or low swale, it has no branches of importance and drains only a narrow strip of the morainal country through which it passes. In its lower course springs, which flow out at the base of the post-Kansan gravels, occur along its banks. This is usually at the surface of the limestone, but may represent the contact line between these gravels and a layer of Kansan till proper.

Willow creek is a stream of minor importance so far as drainage is concerned. It originates among the ponds of western Danville township, and has a well defined channel southward from the middle of section 18 to its confluence with Lime creek. Ledges of limestone appear in its banks along the road in the western part of section 20 and the eastern part of 19. Eight to ten feet of rock are seen more or less covered with talus. The coral reef, as found along Lime creek, is exposed underlain by a crystalline dolomitic limestone. Below this point no stratified rocks are exposed, although the

stream has cut somewhat below the level of the surrounding country rock. The valley is quite generally strewn with Iowan bowlders.

Shell Rock river.—With the exception of Deer Creek township, which is drained by Deer creek, Shell Rock river and its confluents drain the whole of the region of Iowan drift. Shell Rock also receives important branches from the region of Wisconsin drift, and through these tributaries effects the drainage of a considerable portion of the morainal tract. The river enters the county from Minnesota in the northeastern part of Hartland township and, after clipping off a small triangular area in the corner, crosses into Northwood township. Following a general east-of-south direction it traverses diagonally Northwood and Kensett townships and cuts off from the northeast corner of Lincoln a triangular area of about one and one-half square miles, and from the southwest corner of Union a similarly shaped area of practically three square miles, beyond which it passes into Cerro Gordo county. From its entrance into Hartland township to its exit from the Altamont moraine at Northwood, it has a somewhat winding course through a broad drift valley twenty-five to thirty feet below the general upland to the east. Through this region it is generally bounded by low boggy or marshy banks. The depression through which the stream flows averages more than half a mile in width. It is partly filled with hills of Wisconsin drift, which appear as low elongated mounds in the vicinity of Northwood, but have a more abrupt and pronounced character farther up the stream, so that the outlines of the broad valley are more or less obscured in the edge of Minnesota. Beginning in the upper part of section 12, Hartland township, and gradually widening southward to a maximum of one quarter mile at the south line of this section, is a low flat terrace skirting the west bank of the stream. This platform ranges from ten to twelve feet above the water and disappears in the southern part of section 13. The material composing the terrace, as exposed in the river gorge just north of the bridge,

on the road through the middle of section 18, Northwood township, is a gravelly bowlder clay.

Immediately west of Northwood this partially filled valley increases in breadth to nearly a mile, but it narrows considerably within the city limits. Although it has no marked boundary on the east, it is represented quite continually by a flat bottom land to the west of the stream. The bottom land is bounded by hills of bowlder clay and gravel for a distance of two or three miles south of Northwood. This wide valley is gradually lost and beyond this, in the remainder of its course in the county, Shell Rock river occupies a shallow rock-bound pre-Iowan valley which has been only partially filled with Iowan drift. This shallow trough is not generally well defined, and often, on account of its drift disguise, is not noticeable; but numerous instances are found, especially in the eastern part of its course in the county, where the river is unmistakably bounded some distance back on either side by walls of limestone, the intervening space between which is covered with a thin layer of drift and sprinkled with bowlders. The stream has cut into the rock a short distance, usually from four to six feet. This ancient valley is not conspicuous north of the center of Kensett township where rock exposures cease in the banks of the stream. The first striking evidence of it is found in section 27, Kensett, where the wagon road crosses the stream. West of the bridge a few rods, and separated by a ridge from the present channel, is a notable depression which, followed to the north or south, joins the present stream valley. This appears to have been once the bed of the river, which now takes a more direct course. Again, on the township line between Kensett and Lincoln is observed a like instance to the east of the river. Limestone outcrops on the road on the dividing ridge ten to twelve feet above the water, thus making the evidence of a preglacial channel here stronger than in the former case. A low terrace of limestone overlain with drift material quite generally bounds the valley to the east, often twenty to thirty

rods back from the stream, which usually occupies the western side of its preglacial valley and which, on account of its impinging against this side, causes the more abrupt appearance and greater number of rock exposures.

A somewhat exaggerated section across Shell Rock river in section 32, Union township, above the county line bridge, would show the following profile.

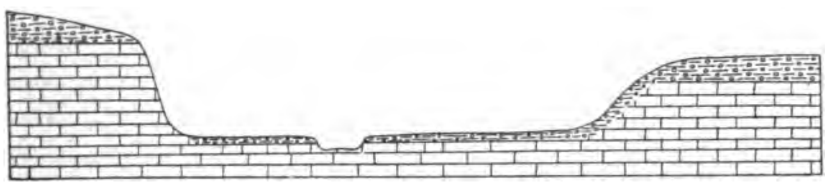


FIG. 39. Profile of Shell Rock river valley in southern Union township. The limestone trough is overspread with Iowan drift to the water's edge and sprinkled with Iowan bowlders.

It seems not unreasonable to conclude that a stream of considerable size must have occupied this channel for some time previous to the Iowan ice. Shell Rock has very few tributaries. With the exception of Mad creek, a small and insignificant stream in western Union less than a mile long, it receives no tributaries whatever from the east. From the west it has only two of importance as drainage lines, Elk and Goose creeks, both of which originate in the region of the moraine.

Elk creek is formed by the confluence of several small branches, the two principal ones joining in section 10, Bristol township. In the whole of its course across Brookfield township and to its confluence with Shell Rock, it is a sluggish stream with low marshy borders. It occupies a broad depression from one-half to three-quarters of a mile wide and from thirty to forty feet deep which, as has been mentioned, apparently once accommodated a much more important stream than Elk creek. This wide hollow is partly filled with Wisconsin drift which, at some places, has somewhat obliterated its borders, but never completely filled it. It passes beyond the limits of the Altamont moraine in eastern Brookfield, and

emerging upon the Iowan this ancient valley is finely displayed by a broad level terrace bounding the stream to the north. The terrace is best developed in section 19, Kensett township, where it rises fifteen feet above the stream. This gradually decreases to the east, giving way to a more or less well defined flood plain along the southern side of which the stream meanders. Although no well data furnishing information concerning the amount of material deposited in this old valley are available, it would seem that the limestone is not far below the surface. West of the road a few rods, in the middle of section 24, Brookfield township, is a small rather abruptly-rounded mound, in appearance not unlike a morainal hill. On closer inspection it was found to be not only rock supported but its mound-like form was partly due to a ledge of limestone which outcropped beneath a cap of gravelly material eight to ten feet above the water. This is evidently a mound of circumdenudation as no other outcrops are found at this level in the vicinity.

Goose creek is a small stream issuing from the marshes and ponds of the moraine. Its headwaters are in Minnesota, and, to within two miles of its junction with Shell Rock river, it is merely a series of connected peat marshes. In its lower course it has a quite well defined valley, but it is narrow and no sensible amount of alluvium has been deposited.

As to the history of Shell Rock river little more can be said. In the upper part of its course the country rock is entirely obscured by glacial drift, and indications are that the river previous to the Wisconsin, and even before the Iowan, had not cut to the underlying rock. The wide drift channel was only partly clogged by the Wisconsin ice, and the stream at present winds among low mounds of drift which it has made little attempt to remove since the ice retreat. The rock-walled, pre-Iowan valley observed in Kensett, Lincoln and Union townships, may be the result of the confluence of two large streams at the point where Elk creek now joins Shell Rock. Preglacial Elk creek was a more important stream

than the present, comparable at least with present Shell Rock river. The old gorge is evidently due to more vigorous water action than is to-day characteristic of the present stream.

Deer creek, the only direct representative of the Cedar river system, is fed principally from the region of the moraine. Both the moraine and the stream enter Iowa at nearly the same point in northwestern Deer Creek township. This creek has cut a shallow channel in the Iowan drift, and reaches the rock surface near the east edge of the county, where it has a narrow drift valley. Deer creek effects the drainage of Deer Creek township, and some small branches carry off the surplus waters from northern Barton township.

GEOLOGICAL FORMATIONS.

GENERAL DESCRIPTION.

The indurated rock strata which underlie Worth county are quite generally hidden by the more or less complete mantle of drift. Save an occasional deep well, the only opportunities for the study of these deposits are found in the shallow gorges of Lime creek and Shell Rock river.

Of the Pleistocene series two formations are represented as surface deposits—the Wisconsin and the Iowan. Although Kansan drift has not been observed in section, its presence is indicated in several ways which will be mentioned under that heading. The sedimentary rocks belong to the Devonian system, and so far as determined are practically continuous over the whole county, with perhaps a gentle dip to the southwest.

In the attempts that have been made to correlate the Devonian strata of Iowa with those of New York, several classifications have been proposed. A certain bed in Iowa would, for example, be found to present similar characteristics to one in the formations of New York, so far as the physical properties were concerned, but with so great a disparity in the fauna contained that a parallelism could not be established. As Professor Calvin has said, so distinct are the

two regions geographically that the conditions of sedimentation were different, and for the same reason the order and succession of faunal conditions were not the same. So that, although the beds of any given epoch in the Devonian period were deposited contemporaneously, the fossil remains may vary widely.

Dr. Owen, in his geologic work on the Devonian rocks of Iowa, correlated them in a general way with the Hamilton, Corniferous and Onondaga groups of New York. In treating of the rocks of the Cedar river and its tributaries, he did not, however, apply any specific name but used the somewhat non-committal terms, "Formations of Cedar Valley" and "Limestone of Cedar Valley." Following Owen, W. J. McGee in his memoir on "Pleistocene History of Northeastern Iowa," has suggested the name Cedar Valley Limestone for the whole thickness of Devonian sediments between the Lime creek or Hackberry shales above and the Independence shales below. Further study of these rocks in Iowa has led to a division in the old "Cedar Valley Limestone" and to the adoption of the title Wapsipinicon stage, including the Independence shales and those layers below the *Spirifer pennatus* beds of Calvin, thus restricting the name "Cedar Valley" to the beds of limestone below the Lime creek shales down to the upper Davenport beds of Norton.

The exposed layers of Devonian rock in Worth county are referable to the upper portion of the Cedar Valley stage. The several geological periods which are represented are grouped and their relations shown in the following table:

GROUP.	SYSTEM.	SERIES.	STAGE.	DEPOSITS.
		Recent.		Peat. Alluvium.
Cenozoic.	Pleistocene.	Glacial.	Wisconsin.	Till.
			Iowan.	Till.
			Buchanan.	Gravel and sand.
			Kansan.	Till.
Paleozoic.	Devonian.	Middle Devonian.	Cedar Valley.	Equivalents of Mason City sub-stage of Calvin.

DEVONIAN SYSTEM.

CEDAR VALLEY LIMESTONE.

A prominent characteristic of the Cedar Valley limestone in Cerro Gordo county, and a more or less constant feature wherever the corresponding horizon is exposed in the state, is the zone of Stromatoporoids. This interesting reef is present at nearly every outcrop of any importance in Worth county. So continuous is it that it is often a very helpful "landmark" in connecting strata from one exposure to another. The distinguishing character of this bed is the presence of the spheroidal and branching stromatoporoids, which even in the incipient stages of weathering present a peculiar and distinctive aspect. The spheroidal forms are the most generally prevalent, and where disintegration of the ledge has gone on to some extent, these being somewhat harder than the matrix stand out, giving a nodular appearance. Often when the matrix is entirely broken down, these spherical bodies, still intact and apparently unaffected by weathering, may be picked up from the material of the talus slope. This layer appears near or at the top of most of the quarries

of Mason City in Cerro Gordo county, but is of very little account economically. Traced up stream along Lime creek it is a constant member at all exposures showing the complete section to water level. In northwest Lincoln township, Cerro Gordo, and southern Danville of Worth county, it crops out about ten feet above the water in Lime creek, and at places forms a low terrace some six or eight rods back from the bank of the stream. Beyond this point it does not appear along Lime creek, but along the banks of Willow creek, a tributary stream from the north, an extensive outcrop appears along the line between sections 19 and 20 of Danville township.

Again, it is found usually capping the low bluffs of the Shell Rock, except where removed by preglacial erosion. Besides the characteristic stromatoporoids, a few genera of corals, with several different species, are found at this horizon. Excellent specimens of these fossils are obtainable at numerous points along the public road running north from the county line between sections 31 and 32, 30 and 29. The outcrops are close to the west border of the Shell Rock valley, and are sufficient to fully establish the location of the ledge in the Cedar valley series. The rocks exposed in the gorge of the river contain no fossils, yet the characteristic nodular appearance of the weathered ledge above is enough to unmistakably settle the question of the identity of the terrane.

Paleontologically the remaining strata of the Cedar Valley terrane are quite barren. Small cavities, which are probalby fossil moulds filled with calcite, are found in some layers, but the organic structure is so entirely destroyed that practically no forms could be recognized with certainty.

The Cedar Valley strata which outcrop along Shell Rock river may quite generally be recognized as continuous from one exposure to another. But because of numerous small folds which characterize these rocks in this region, the thickness of any given stratum may vary greatly in a distance of only a few rods. Hence the impossibility of assigning definite

thicknesses to the strata. Along this river the beds of limestone may be observed with a maximum thickness of twenty feet, from the railroad bridge to section 1, Lincoln township, to their disappearance beneath the drift in the vicinity of Northwood, and with a minimum thickness of three or four feet near the south county line. This variation in the exposed thickness does not appear to be due to a widespread flexure in the strata with its crest in the northern part of Lincoln township, but is rather due to the fact that the stream impinges against the low walls which restrain the valley at this point and thus exposes a greater thickness of beds. Where it pursues a direct course, holding strictly within the bounds of its ancient valley, it has cut into the rock usually to a depth of four to eight feet since the retreat of the Iowan glaciers. But where, in its meanders, the stream had cut into the confining walls of its pre-Iowan valley the maximum height of rock exposures is the result.

TYPICAL SECTIONS.

At the county line bridge across the Shell Rock in southern Union township, a low ledge of limestone, which may be traced northward in a series of low folds, flanks the stream and shows the following section:

	FEET.
2. Very coarse gravel with numerous limestone bowlders	15-20
1. Hard, compact limestone, containing some calcite concretions and badly weathered at the top	5

In a low fold about one-half mile south of Foster's mill, near the northwest corner of section 29, a layer not noted in any section previously observed north of the county line bridge, is brought into view. This consists of a dark-colored, argillaceous and more or less crystalline rock of uniform texture. It is here barely shown above the water in the arch of the fold and disappears in both directions in a few rods. At Foster's mill a total of eighteen feet is exposed:

		FEET.
4.	Weathered limestone, crystalline, and containing numerous calcite cavities	10
3.	Compact, light-colored, dolomitic limestone, heavy bedded	4
2.	Very clcse-textured limestone, lithographic in appearance, hard and breaking with conchoidal fracture. Has a very characteristic ring when struck with the hammer	3
1.	Argillaceous, dolomite layer, exposed to water below dam	1

The weathered stratum at the top appears sandy and is an advanced stage of disintegration, and for this reason is usually spoken of as sandstone. But from the fossil stromatopores found in the road directly west of this exposure, and only a few feet higher, and the characteristic nodular weathering, it is seen to be referable to the stromatoporoid beds of the Mason City section.* It is here more or less dolomitized and presents the same distinguishing characters as in Cerro Gordo county. The dividing line between beds four and three is usually quite marked, while often between three and two no sharp line of contact can be made out. Gradations from one to the other occur, and sometimes a thin layer of earthy dolomite is found intercalated between layers of hard, light-colored limestone. Number three from its general appearance, weathering and relative position in the series, may be correlated with the layer of limestone appearing below the stromatoporoid reef in the Mason City section. While in some of the quarries at Mason City this stratum reaches a thickness of fourteen to fifteen feet, it does not at any outcropping in Worth county attain to more than eight or nine feet, and it often thins down to one foot and a half. The lower member of the section following the same sequence is the equivalent of the Mason City dolomite in Calvin's section for Cerro Gordo county.

Below Foster's mill the strata have a decided dip to the south, while north of the mill they dip in the opposite direction. The mill is situated just south of the crest of a fold (a

*Iowa Geol. Surv., Vol. VII, p. 169.

natural mill site) which is followed to the north by several perceptible oscillations with crests only a few rods apart. This exposure is terminated to the north by a V-shaped ravine evidently cut into the rock previous to the deposition of Iowan drift, as it is partially filled with this material.

A short distance above the wagon bridge, on the section line road above Foster's Mill, is a small quarry in which the white limestone (No. 2 of Foster's Mill section) appears about four feet above the water and attains a thickness of two feet. Above this is a thin layer of the more or less dolomitized limestone as observed at Foster's Mill. This is covered at the surface with a foot and a half of alluvial material containing some small pebbles. At water level is a somewhat argillaceous dolomite, lighter colored than that below the mill, but in position its equivalent.

In Lincoln township, just above the point where Shell Rock enters section 13, is a quarry in which is exhibited four to five feet of compact limestone which grades downward into a coarser textured white limestone. Below this to water level the beds are covered with talus. The upper dolomitic limestone is represented by a few feet of weathered rock with an almost arenaceous structure and containing fragments of fossils. One good specimen of spheroidal stromatopora was found.

The middle layer of white limestone is here prepared for road material by crushing, and a considerable amount has been removed for this purpose. Although occasionally employed as a building stone, it is very unstable for structural purposes. Weathering has a very marked effect upon it even when it is exposed for short periods of time. Especially is it liable to injury by the action of frost. Sudden changes in temperature cause it to spall or chip off, and, when viewed in exposed ledges, it is often broken up into polygonal blocks by a series of transverse and vertical cracks; its most persistent splitting being along lamination planes.

A few rods north of the bridge on the section line between 12 and 13, Lincoln township, a gentle fold brings the stratum of argillaceous dolomite above the water in the same relative position as below the mill. Only one foot of light colored limestone is present between the darker dolomite below and the more or less dolomitized layer above. All are unfossiliferous, but the upper member often shows a slight brecciation. The bedding of the argillaceous layer is usually in ledges from eight inches to a foot or fifteen inches thick. The peculiar brown color seems to be partly due to the process of weathering rather than to the stage of dolomitization. Where the bedding is heaviest, the central portions of the ledge, or that part farthest from bedding and joint planes, is usually of a dark bluish cast. Along these planes water percolating from above, with organic matter in solution, has a chance to act upon the rock substance, thus modifying its composition wherever it comes in contact. Where this rock is exposed to the direct action of running water the outer surface is altered to a dark rusty brown color and forms a thin protecting coating through which disintegration progresses more slowly than where exposed more generally to all the atmospheric agencies. The wearing away is due more to the attrition of particles carried in suspension in the water than to rock decay.

On the east side of the road bounding section 1, Lincoln township, on the west, on the Jewett farm, is a small rock exposure in the side of a shallow ravine. Six feet of the compact limestone are in view, the upper two feet of which are badly shattered by weathering. This upper portion is quite filled with the stem-like cyathophylloid corals, which are also sparsely present through the lower strata of the outcrop. Stromatoporoid growths were found, but in a poorly preserved condition. Aside from doubtful casts, this is the only outcrop of the Mason City limestone in Worth county, at which fossil remains were not unquestionably found in place.

Beginning in the northwest quarter of section 1, Lincoln township, is a continuous outcrop for about one-third of a

mile where Shell Rock river flows close to the west edge of its valley and at the foot of the exposure. From a short distance below the railroad bridge it extends northward across the line into Kensett township. The following is the somewhat generalized section:

		FEET.
5.	Bowldery drift	2
4.	Badly weathered limestone, rusty red in color, no fossils, nodular in appearance, bedding obscure on account of disintegration	6
3.	Fine textured limestone of light color, non-fossiliferous and containing much crystalline interstitial calcite, heavy bedded	3
2.	Slightly argillaceous magnesian limestone, grading downward into the darker variety, breaks with earthy fracture but is very hard, bedding 8 to 12 inches	2-3
1.	Argillaceous dolomite, that portion not adjacent to joint or bedding planes a dark blue, good building stone, to water	6

No. 5 of this section is the equivalent of the upper member in the Foster Mill section. Although no fossils are found in place, the characteristic weathered face is sufficient data for the correlation. Below the railroad bridge a layer of calcareous sandstone eight inches thick appears between Nos. 3 and 2. This is very susceptible to the weathering agencies, and its breaking down forms a re-entrant in the quarry face.

The entire exposure is a series of gentle flexures, but broadly the dip is slightly to the south. At the extreme north end of the outcrop, north of the wagon bridge on the township line, a rather abrupt dip brings the limestone stratum No. 4, nearly to the level of the water, where it disappears beneath the drift. This limestone cliff serves as a natural abutment upon which the west end of the bridge is anchored.

An interesting example of the manner in which a stratum may sometimes "feather out" is exhibited just north of the wagon bridge. Here a thin bed of limestone, No. 4, is intercalated between layers of the argillaceous dolomite near the center of the quarry face. An abrupt bend in the strata

occurs at this point, displacing each one more than a foot almost vertically. At the crest of this fold the intercalated layer has its uniform thickness of eight to ten inches. Immediately north of the crest, and down the limb of the fold, it rapidly thins, feathering out completely in the short

FIG. 40. Rock exposure in northern Lincoln township, Stromatoporoid zone a thin stratum of compact limestone beneath, which is the dolomite. The hammer marks a low fold due to rapid thinning of a certain layer.

space of two or three feet and before reaching the synclinal limit of the flexures. Other cases of this kind were noticed at different exposures but none so strikingly conspicuous as the above. The river here comes from the northeast and is undoubtedly the causal agent which has produced the escarpment. Some stone has been quarried, the lower dolomitic layer being the most important as a building stone.

A little south of the road through the middle of section 26, Kensett township, and a short way east of the river bridge, is an artificial exposure from which a small amount of stone has been removed. The rock here quarried is the lower magnesian limestone of previous sections. A depth of four feet taken out makes the bottom of the exposure about water

level in Shell Rock. The close textured limestone, No. 2, of Foster's Mill section, is barely represented by a layer so thin and badly broken that it can with difficulty be found in place.

Outcrops in the bank of the stream showing low folds are found north of the above mentioned bridge. Phases are here observed that have not been present in any previous exposures. These folds usually have at the top a thin layer of the light colored limestone, No. 2, of Foster's Mill section. Beneath this is a six to eight inch stratum of light brown dolomite containing a few cup corals. To the water, two or three feet, is a very fine-grained and magnesian limestone which is decidedly brecciated. The matrix is a fine, close-textured limestone, while the contained fragments appear to be dolomitic.

A small quarry has been opened in the northern part of section 14, Kensett township, and some stone removed to supply a local demand for the purpose of rough masonry. The argillaceous dolomite has here been quarried to a depth of six feet. A thin layer of sandy, shaly and weathered limestone occurs between strata of the dolomite. All the layers shown at this exposure now suffer more or less from weathering and are of little value as building material.

No other exposures north of the point last described were observed. Limestone bowlders along the bank, and the character of the bed of the river, indicate that the stream has eroded the rock slightly, nearly as far north as the northern boundary of Kensett township.

At Northwood no limestone is visible in place, but all indications imply that the Shell Rock here runs at about the level of the indurated rock surface. Wells in Northwood average from twenty to thirty feet to rock, which is about to the level of the bed of the river.

It will be noted from the map that all of the rock exposures of any consequence along Shell Rock river, and those for which the stream is in any measure responsible, are found along the west bank. The same causes seem to be at work

here in determining the position of this river relative to the boundaries of its old valley, as are active in the valley of Lime creek. Less resistance is encountered in corrading its channel down the dip of the rock strata and in the direction of the planes of stratification. Shell Rock is another example of a strike stream, and the usual tendency with such drainage lines is to widen their valleys in the direction of the slope of the country rock. As in the case of Lime creek, the factor of differential weathering in the two sides of the shallow trough-like valley might also aid in producing the observed conditions, but probably is not so important a factor as with the former stream.

Along a small stream which flows through southern Lincoln and joins the Shell Rock at Plymouth, in the edge of Cerro Gordo county, both No. 2 and No. 1 of the Foster's Mill section are exposed. The stream has cut four or five feet into this limestone in its meanders along the county line in the southern part of section 36 of Lincoln township. The upper layer is much shattered at the surface, breaking up into small polygonal blocks. The magnesian limestone is barely exposed at the bottom of the creek.

Limestone has been taken from the bed of Deer creek below the wagon bridge, near the south line of section 35, during seasons when the creek has been dry. There are no exposures along its banks, showing that the stream, in its lower course in Worth county, flows at the surface of the rock, into which it gradually deepens its gorge as it proceeds across Mitchell county to the east. Only a small fragment was obtainable to show the nature of the beds removed. This showed a dark color and coarsely crystalline texture so much weathered as hardly to be fairly representative of the parent ledge. It is probably referable to the lower dolomitic phase in the sections along Shell Rock river.

A railroad well at Manley, in southern Lincoln township, furnishes the following section from drillings collected by Mr. D. Knowles:

		FEET.	FEET.
21.	Alternating layers of gravel and quicksand....	50	50
20.	Limestone, blue-gray, compact; brittle, more or less uneven fracture, and tendency toward mottling..................................	5	55
19.	Same as above, except mottling................	5	60
18.	Limestone with fragments of dark, gray-blue, porous, dolomite, drillings much mixed.......	5	65
17.	Limestone, light-gray; drillings sharp.........	5	70
16.	Dolomite, blue-gray, saccharoidal, with minute caverns..	5	75
15.	Same as above, but darker, and becomes more earthy and cavernous; quartz, pebbles and angular fragments probably from above......	5	80
14.	Same as 15....................................	5	85
13.	Same as 15....................................	5	90
12.	Dolomite, dark blue-gray, mottled with black; finely saccharoidal in texture.................	5	95
11.	Same as above, lighter in color................	5	100
10.	No sample......................................	5	105
9.	Same as 11....................................	5	110
8.	Dolomite, very dark in color..................	5	115
7.	Same as No. 11................................	5	120
6.	Dolomite, gray, sub-crystalline, the same as 16.	5	125
5.	The same, with limestone fragments and crystalline calcite..........................	5	130
4.	No sample......................................	5	135
3.	Limestone, gray, with pieces of marly limestone	15	150
2.	Limestone, light-gray; chert abundant.........	25	175
1.	Same as above, no chert in sample............	10	185

This is the only well in the county in which so great a thickness of the Devonian rocks has been penetrated. It is of special interest as showing the entire thickness of the Mason City dolomite in Worth county, of which forty feet are exposed in Cerro Gordo county. Samples five and sixteen, inclusive, show alternating zones of light and dark-gray dolomite to a thickness of fifty-five feet. Below the dolomite is a limestone which probably corresponds with the Lower Devonian limestone indicated in Norton's section of the Mason City deep well† and represents the base of the Devonian for the region.

Limestone of the Cedar valley stage, into which the stream has eroded its shallow channel, is exposed along Lime creek.

†Iowa Geol. Surv., Vol. III, p. 188.

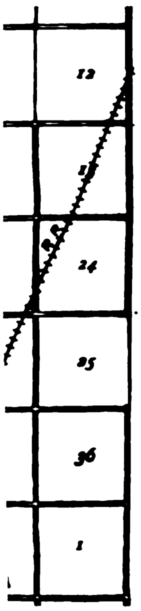
Near the southern line of section 31, Danville township, where the stream channel crowds closely the northern limit of its valley, is a low outcrop of four to five feet, showing an arenaceous, weathered and more or less crystalline limestone underlain by a layer of thinly bedded, light-colored lime rock to water level.

At Fertile an outcrop in the south bank of the stream, below the wagon bridge, gives the following section:

		FEET.
3.	Hard limestone, badly shattered into small blocks by weathering	4½
2.	Arenaceous shaly limestone, very slight effervescence with dilute HCl	8
1.	Heavy bedded, sub-crystalline, dolomitic limestone to water level	5

Bed No. 2, giving way much more readily to weathering than the other members, is conspicuous as a re-entrant along the face of the exposure. At a level about six or eight feet higher than the bridge at the east end of the main street of Fertile, stone containing numerous cavities filled with crystalline calcite, outcrops in the road. Many of the cavities are probably fossil casts, but so poorly preserved as not to be certainly recognizable as such. South from Fertile, in the banks of Lime creek, the same sequence of strata is shown. The thin shaly layer here weathers into a plastic light-blue clay. The upper layer is a partly crystalline rock with small calcite cavities and presenting a sandy appearance when weathered. Beneath the clayey stratum is a dark-colored, argillaceous limestone weathering to a bluish cast. It is readily affected with hydrochloric acid and effervesces freely. The strata here dip quite perceptibly to the south, so that layers appearing a few feet above water may be traced southward until they disappear below the bed of the river.

These are the highest and, therefore, youngest indurated beds observed in Worth county. In the Devonian column they would come above the reef of stromataporoids and probably be included in No. 6 of Calvin's "Generalized section of



BY

IRA A. WILLIAMS.

1900.

Scale $\frac{1}{125,000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

Cedar valley limestone in Cerro Gordo and adjacent counties."*

LIME CREEK SHALES.

There has not yet been found any certain evidence of the presence of these shales in Worth county. Projecting the line of strike from known exposures in Cerro Gordo county, it would lead across the southwest corner of Worth, and it is probable that beds of shale may underlie the heavy deposits of drift by which all the indurated rocks are obscured in western Fertile township. Wells sunk in this section do not go to rock for their water supply, so that no information can be gained by this means. It is believed that the broad valley of Lime creek, widely excavated in the country rock, may, in part, account for the absence of these shales, if they ever were present.

PLEISTOCENE SYSTEM.

Members of this system representing at least four different stages are present in Worth county. These may be grouped into three of glaciation or times of drift deposition, and one interglacial stage or time of deglaciation. Deposits referable to the first stage of glaciation anywhere recognized in Iowa, the sub-Aftonian,‡ are certainly not found in this region, but well sections at different points reveal the presence of bowldery material below that which is directly referable to the Kansan, and suggests the possibility of an earlier drift sheet. The presence of Kansan drift is indicated by well sections in different parts of the county. The time following the Kansan period of glaciation to which the name Buchanan has been given from typical deposits of that age in Buchanan county, is represented by quite extensive deposits of gravel and sand. This age was brought to a close by the on coming of the Iowan ice, and material from Iowan glaciers is abundant over the greater portion of the region under consideration. No deposits are found in the area of Wisconsin drift referable

* Ann. Rept. Iowa Geol. Surv., Vol. VII, p. 160.

‡ Iowa Geol. Surv., Vol. VII, p. 171.

to the interglacial stage, Peorian, between the Iowan and the Wisconsin ice. Practically half of the county, as outlined on the map, is occupied superficially by the heterogeneous materials of the Wisconsin drift.

KANSAN DRIFT.

The relations of the Kansan drift sheet in Worth county to the overlying Iowan are such that it is difficult to distinguish the one from the other. There are, however, several things which point to the presence of Kansan drift. Worth county is included within the area over which the ice moved and deposited its load during the early and maximum advance of the Keewatin glacier. For this reason bowlder clay and gravel underlying the Iowan, which is usually only a few feet thick, may reasonably be referred to the Kansan stage for want of better evidence for referring it to a still earlier till. As has been pointed out by Calvin,* the deposits of gravel along Lime creek and other small streams, overlain by a layer of Iowan till, represent the interglacial period preceding the Iowan stage of glaciation. These deposits necessitate the presence of a pre existing drift sheet from which they were derived. In the boring of wells over the eastern part of the county, pieces of partly decayed wood are often encountered at varying depths. Where found between layers of drift clay, these may represent an old forest bed of interglacial growth; or, they may be found incorporated in the body of the Iowan material, in which case they may have been transported some distance. Nevertheless, they are indicative of a pre existing soil. It is admitted that the evidence is far from conclusive, but, when taken in connection with other facts, it favors strongly the assumption that this was a glacial soil. In the region of Shell Rock river where Iowan drift is often observed lying directly upon the country rock, and where no older glacial deposits are present, the drift seldom exceeds eight or ten feet in thickness, and this where apparently no erosion

*Iowa Geol. Surv., Vol. VII, p. 171.

has taken place since deposition. The Iowan drift, wherever studied, although covering hill and valley alike, is known as a relatively thin sheet in comparison with other till sheets; a mere veneer over the surface of the country. In southern Union, Lincoln and Danville townships thicknesses of drift ranging from forty to one hundred feet are found above rock and consist of alternating beds of clay, gravel and sand. Allowing twenty feet for Iowan, which is more than an average, the lower layer, in part at least, may be correlated with the Kansan.

On the farm of H. H. Schulte, on section 26, Danville township, a well drilling shows the following sequence of strata:

		FEET.
1.	Soil	2
2.	Yellow clay	18
3.	Sand, water	1
4.	Blue clay, mixed	59
5.	Sand, water	4
6.	Soft blue clay	4
7.	Alternating sand and clay	10
8.	Coarse gravel	7
9.	Rock encountered	
	Depth	105

One and three are undoubtedly Iowan drift. Three to seven, inclusive, are probably Kansan. Eight, pre-Kansan gravel which may be due to an older drift. Other wells, over the Iowan area, encountered the so-called hard-pan, or gumbo layer, which sometimes defies all efforts to sink a drive well through it, and often is an impediment to progress with the ordinary auger. It is a very compact blue clay, and may represent the upper surface of the Kansan drift.

BUCHANAN GRAVELS.*

Gravels of this age are found in the terrace which bounds Lime creek, and underlie an area in southern Danville and Fertile townships within this valley, varying from one-half to more than a mile in width. They are underlain by a terrace of limestone which is somewhat above the present stream

*Iowa Geol. Surv., Vol. VII, pp. 172-211.

valley. These are usually composed of very coarse material, and the bowlders are more or less weathered and broken down, so that many of them crumble readily. The gravel is used for road building, and is removed for this purpose along Willow creek in the middle of section 29, and at the southwest corner of the same section, Danville township; also in the banks of Winan creek south of the road through the center of section 25, Fertile township.

During recent excavations for a railroad line these gravels were exposed at several points in sections 30, 32 and 33 of Danville. In a cut in the southwest quarter of 33 four feet of very coarse gravel are in view, overlain by a thin stratum of soil. Above the schoolhouse in the southwest corner of section 32 the following order of strata is shown:

	FEET.	INCHES.
3. Iowan drift, the upper two feet modified to brown soil	5	
2. Coarse gravel, iron stained and weathered	1	6
1. Coarse, clean gravel	5	

The railroad is here laid on the plane of the upper terrace, and in its course across section 30 is ballasted with Buchanan gravel, which was usually found beneath only a few feet of Iowan drift, and taken out quite continuously from the side of the road bed.

Gravels of Buchanan age are probably represented along Elk creek, outside of the Altamont moraine, in the terrace which skirts this stream to the north, but their relation to the two drifts here present cannot as yet be definitely stated.

The retreat of the Kansan ice was attended with floods of water which filled to overflowing all of the depressions marking the former courses of streams. That these were swift currents carrying large volumes of water is evidenced by the coarseness of the material carried and laid down by them, and also by the fact that these deposits are only irregularly stratified. The deposits consist of fragments of rock from fine sand to slabs measuring more than six inches across. In the exposures examined these are dumped in together, with little

of the order that is generally characteristic of water-laid deposits.

IOWAN DRIFT.

Materials from the Iowan ice sheet are almost universally present over that portion of the county which is not occupied by the Wisconsin drift. They generally constitute a thin sheet of till which, so far as can be made out for Worth county, varies from naught to twenty feet in thickness. Exposures showing the complete section of Iowan drift above the Kansan were not seen, so that in discriminating the two, well data must be depended upon, which, as has been indicated, are not altegether reliable. The Iowan is thinnest in the region of Shell Rock river, where it may be seen lying uncomformably upon the sedimentary rocks. In places along this stream channel the large and conspicuous granite bowlders are often the only indication of ice invasion. In the eastern part of the county wells show that the depth to rock varies from three to ninety feet. Within the limits of Barton township forty feet is the maximum limit, but a thicker layer of drift material is found in southern Union and Deer Creek townships. In no place, however, is the blue clay more than fifteen feet below the surface. Accepting the blue clay as Kansan drift, the Iowan drift is then represented by a comparatively attenuated layer varying from a few inches to fifteen feet.

In western Lincoln and Danville townships the total thickness of drift varies from forty at Manly to more than 100 on section 26 of Danville, as has been mentioned under Kansan drift. But of this assemblage of clay, gravel and sand quite generously spread over the surface of the land, only the uppermost layer of yellow bowlder clay, which scarcely exceeds twenty feet, can be referred to the Iowan stage. In the old valley of Lime creek Iowan drift forms a thin coating over the surface of the Buchanan gravels. It is never more than three or four feet thick, and often not sufficient to hide

bowldery gravel which crops out in road beds and on side hills.

The materials of this drift are porous bowlder clay interspersed with pockets of gravel and sand. The color varies little from the dark yellow several feet below the surface to the light

FIG. 41. A field of Iowan bowlders in northwestern Lincoln township.

brown immediately beneath the soil layer. It is rich in calcium carbonate and effervesces with dilute hydrochloric acid even in the surface layer of soil. Perhaps the most conspicuous surface feature is the large granite bowlders. Where none have been removed these often present an appearance not incomparable to a distant flock of sheep, and many acres are strewn with rock fragments from one or two feet to many feet in diameter. The prevailing type is the red granite. These are usually coarse-grained, and sometimes show striated or glacial planed surfaces. A large rock of this species is located in the northern part of section 14, Kensett township. It rests almost directly upon the limestone. It is made of large flesh-colored crystals of orthoclase feldspar with quartz. The dimensions were not accurately determined, but it is somewhat more than twelve feet high, twenty feet long and

ten to twelve feet wide. Among a certain class of inhabitants of the immediate neighborhood the question whether or not a large deposit of gold might be found in the interior of this monster is a prevalent one. Gray granites are common, and specimens of the darker basic rocks are not exceptional.

WISCONSIN DRIFT.

It was during the latest ice epoch recorded in Iowa that the hills of the Altamont moraine were built, and the glacial material strewn over western Worth county. So short a time have the agents of degradation acted that the existing land forms are essentially those fashioned by the retreating glacier. Modification of the material thus laid down has progressed to only a slight extent. In general it consists of a yellow clay containing many bowlders of all sizes, all textures, and all species. So unweathered and unleached is this bowlder clay that when first exposed, as in a new road cut, its extremly light yellow color, often nearly white, makes it conspiouosly visible at some distance. With dilute hydrochloric acid effervescence takes place almost as freely as with a pure limestone, thus indicating the source of the material making up this sheet of till. All grades of fineness are found from the comminuted limestone clay to the beds of coarse gravel.

Near the margin of the Wisconsin drift the surface is very much broken. Knobs and ridges are very common, often separated by ponds and swales. The salient features are usually composed of compact bowlder clay, showing little if any stratification. In a railroad cut through a prominent rounded knoll in section 24, Fertile township, the unstratified condition is clearly shown, as also in numerous road cuts at other places in the morainal tract. From the fact that true kames and eskers are rather rare, the few examples which do occur are of more than ordinary interest. In the old valley of Elk creek these types of land forms predominate as has been stated under topography. North of the middle of section 10, Bristol township, was observed a small section of a

kame-like ridge composed entirely of gravel and sand. These materials were plainly interstratified, thus giving a definite clue to the agent that aided in their deposition. In this and in others observed in this region the bedding of the strata is not horizontal, but dips in each direction from the crest of the ridge. Cross bedding in a single layer is also more or less obvious, showing that the conditions which existed when these deposits were laid down differed from those that surround our streams to-day. These deposits are probably due to subglacial streams which were confined above and to either side by walls of ice.

An exposure of drift in the northeast quarter of section 15, Fertile township, furnishes a section which is of interest, not alone from the sequence of layers displayed, but as showing certain structural features as well. A morainal hill is here dissected for a railroad track. This is a somewhat rounded knoll bordering the low marshy swale through which Winan creek flows. About twenty-two and one-half feet are exposed in the following sequence:

		FEET.	INCHES.
5.	Bowldery soil	1	6
4.	Gravel, imperfectly stratified	6	
3.	Sand, apparently somewhat stratified	5	
2.	Very fine sand, grading from 3 into a homogeneous, unstratified material containing numerous root casts composed of $Ca\ Co_3$	8	
1.	Arenaceous light-blue clay to road bed	2	

The upper layers of soil, gravel and sand are laid symmetrically with the present contour of the hill, but from 3 to 2 of the above section, although apparently a gradation, the bedding shows two low rounded mounds which are fused into one by the upper layers. The material responsible for these sub-contours is a very fine, calcareous, silty substance not unlike the loess of central Iowa; practically no pebbles larger than sand grains are found below the gravel stratum. The sand of 3 contains numerous rounded clay bowlder balls from one to six inches in diameter. These, when dry, may be crushed with the pressure of the hand. All the layers below 4 contain

root casts made of pure calcium carbonate, most numerous, however, in the layers of No. 2. They are sometimes hollow, but often contain the root fragment around which the concretion has formed. The light-blue clay at the bottom is arenaceous, but also effervesces very freely when tested for lime

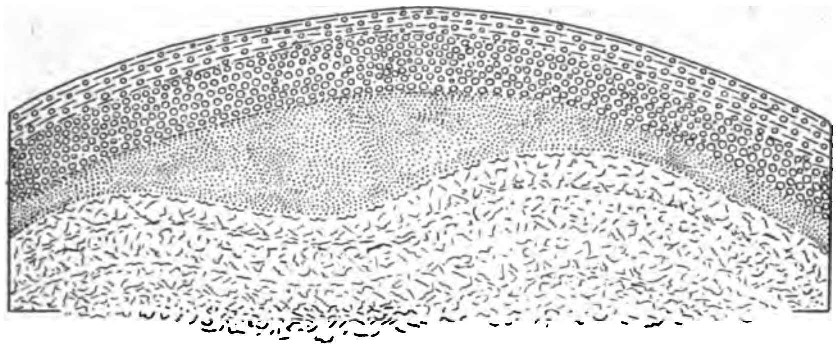


FIG. 42. Section of morainal till on section 15, Fertile township.

Extending through all layers below the gravel, sometimes vertical, but usually inclined, and often intersecting

FIG. 43. Faulting in Glacial clay. It is shown best at the extreme right.

each other, is a series of faults which have in some cases displaced individual layers more than a foot. This displacement

is made evident by the alternation of wet and dry strata in the lower part of the exposure. The following figure will illustrate the faulting observed in a portion of a single wet band a little to the right of the center of the section and at the crest of the broader subundulation:

Although the upper beds of loose sand are affected by this faulting, it is not so evident on account of slipping, which has more or less obliterated all structural features. Along these fault planes appear the greater number of root casts, probably because the roots of plants found here a place of easy penetration. These casts also appear scattered promiscuously throughout the whole mass, and, on account of the removal of material by the wind, often protrude from the surface from one to two inches as minute hollow cylindrical columns of calcium carbonate.

Although no definite contact line which would mark an interruption in the deposition of the material of the hill can be made out, it seems probable that here are represented two stages of deposition, and possibly the work of two different agents. Two small undulations are here developed with a later deposit of gravel and sand, making a single rounded knoll. It is not probable that the non-horizontal position of the strata is due to the later melting of included bodies of ice, for in this case any irregularity would be expressed at the surface. This, however might account for the faulting, but when considered in conjunction with the character of the lower material, root casts, etc., this explanation is rendered insufficient. In comparison with the material of the loess deposits of central Iowa, this is of a coarser sandy texture, and is, perhaps, more calcareous. No molluscan remains, such as are quite generally characteristic of the loess of Story, Marshall* and other central counties, were found. With these slight variations it is very similar to ordinary loess. From the prevailing presence of root casts, many of which contain the woody fibres of the roots themselves

*Iowa Acad. Sci., Vol. VI, pp. 98 and 117.

and which almost universally assume a more or less vertical attitude, it may be inferred that these are remains of plants *in situ* and not transported. In short it would appear that here are exhibited deposits representing two stages of Wisconsin glaciation. The lower portion of this section may be due to loess-depositing agents, be they wind or water, or the two combined. The section may record (1) a retreat of the ice sufficiently long to allow of plant growth, and (2) a readvance which may have scoured off any accumulated soil, and which deposited the upper layers of sand and gravel. The balls of bowldery clay in the layer of coarse sand were undoubtedly frozen when deposited, for otherwise they would not have withstood the rough usage to which they were subjected. It will be observed that the direction of the planes of faulting bear no constant relation to each other. Although in a general way somewhat parallel, they often intersect at high angles. These may be the result of the pressure of the superincumbent ice, or may be due to differential settling.

The aggregate thickness of drift deposits over the area covered by the Wisconsin ice scarcely ever exceeds 125 feet. A creamery well on section 18, Hartland township, gives the following record:

		FEET.
5.	Soil	2
4.	Yellow clay	15
3.	Coarse gravel with water	4
2.	Gravelly blue-clay	60
1.	Rock, cherty	30

Wells in Silver Lake township show a greater distance to rock, but it is exceptional to find more than 150 feet of drift deposits. The Iowan, if present, cannot be differentiated from the Kansan in well sections. Neither the Wisconsin nor the Kansan reach here the thickness which they attain in the central part of Iowa, where the Kansan alone often exceeds 200 feet, and the Wisconsin more than fifty feet on the general upland.*

*Iowa Geol. Surv., Vol. VII, p. 229; also Vol. IX, p. 198.

In distinguishing the Wisconsin drift from the Iowan, aside from topography, two principal points of difference may be noted. First, the character of the contained bowlders. While on the Iowan the prevailing type is the red granite, with a relative scarcity of the darker rocks, on the Wisconsin

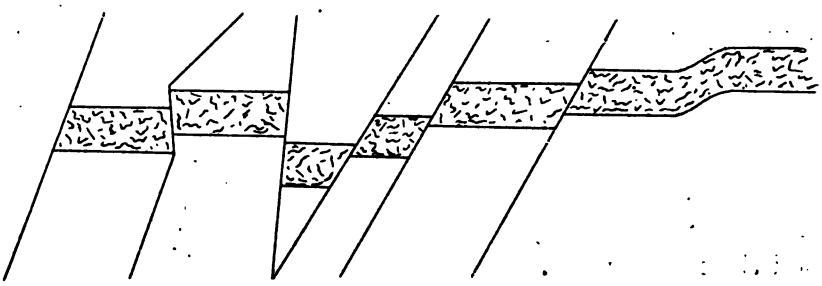


FIG. 44. Diagrams showing displacement by faulting in a single layer of clay, slightly over a foot in thickness.

the gray granites predominate, and, although comparatively fewer in number, the red and pinkish granites are not rare; but neither reach the prevailing large size of the Iowan bowlders. In the Iowan drift limestones are common, but not in the proportion that they reach in the Wisconsin. At any exposure of the latter drift numberless fragments of limestone may be found from the size of a pebble to that of a slab several feet long, and in some cases these seem to predominate, with an almost total absence of other species of rocks. It seems probable, therefore, that the greater portion of the rock debris carried by the Wisconsin ice was derived from the limestone areas over which it passed. Pieces of sandstone are frequently found, and both limestone and sandstone fragments are sometimes fossiliferous. Members of the dark colored basic rocks, greenstones, diabase, gabbros, etc., are quite numerous, but do not often occur above the size of the cobblestone. One instance was observed where a dark brown micaceous bowlder, exceeding a foot in diameter, had been severed in making a road cut, leaving half of the bowlder still imbedded in the matrix of yellow clay. The larger bowlders of this group are usually more or less crumbled from weathering.

While in one drift section it might be impossible to tell, after applying the diagnostic tests for each, whether the drift be Iowan or Wisconsin, in general the bowlder clay of the Wisconsin is more compact, contains less sand intermixed, and is more impervious to water. Although oxidation and leaching of the soluble constituents have not gone on to any extent in the Iowan, in comparison with the Wisconsin it is usually more or less iron stained and the calcareous contents partly removed by percolating waters, so that in distinguishing the two drifts it is seen that the more recent is unleached, has the ferreto zone little developed, and has a shallower soil.

ALLUVIUM.

With the exception of a very small amount of alluvial material at places along Shell Rock river, probably laid down during stages of high water, and a perceptible amount spread over the floor of Elk Creek valley outside of the Altamont moraine, there are no bodies of alluvium sufficient for mapping in the county.

ECONOMIC PRODUCTS.

SOILS.

In the broad extent of fertile soils lies the greatest and most enduring wealth of Worth county. As in other prairie regions, much of the progress and comfort of that small proportion of the population engaged in other occupations depend upon the tiller of the soil. The soil, as a source of wealth, is not yet developed to its full capacity. In areas of timber growth, with which the Wisconsin drift is more generally characterized, a great deal of the farming has been made possible only through long processes of "grubbing" and clearing, and large fields have thus been brought under the plow. After a few years of cultivation these cleared farms become very productive, rivaling the open prairie soils for the raising of small grain, and even surpassing them in the production of the universal and most important crop, corn. It was the grass covered prairies that, as a farming country, attracted the early

settlers to northern Iowa. At present the level plains of the Iowan drift region, which occupy the eastern half of the county, and which, in "days gone by," presented the most typical prairie aspect, are nearly universally under cultivation. An occasional strip of native prairie grass, occupied by a swale or slough, is seen, but it is quite unusual to find an area of any extent unaffected by the processes of agriculture unless on account of the physical conditions of the soil itself.

In general, the soils of Worth county belong to the drift type. In the neighborhood of Shell Rock river, where in places the drift is exceedingly thin, the underlying limestone has undoubtedly lent more or less to the process of soil formation, but not in sufficient amount to be appreciable in the elements necessary to plant growth. Here, as elsewhere over the county, the miscellaneous materials of glacial debris are almost entirely responsible for the constituents of the soil. Atmospheric agencies at the surface, water working its way down through the clayey till, the roots of plants and decaying vegetable matter, with its humus accumulating year after year, are the principal influences that have been at work upon these glacial deposits since they were laid down by the ice.

It is, therefore, evident that the older drift would show a soil more highly modified, and developed to a greater depth, than a newer till sheet. In the two drifts exhibited as surface deposits in Worth county such is found to be the case. On the Iowan in places where it has apparently undergone no loss by denudation, nor been added to by transported material, the process of oxidation and leaching has gone on to a depth of several feet, and the plant roots have usually penetrated a considerable distance beyond the depth stirred by the plow. The true soil layer is usually a black loam, rich in calcium carbonate, and grading into a porous, clayey subsoil. Small bowlders and pebbles are included, but these near the top are somewhat decayed and more or less comminuted so that they offer no hindrance to tilling of the land. It is especially

adapted to the cultivation of the cereals. The prosperity of the people on this productive soil is attested by the many fine farm houses, large and well constructed outbuildings and seldom a field of any size that is not surrounded by a well kept wire fence.

The soils of the western part of the county, in the region of the Altamont moraine, are relatively newer. Modification of the surface has not progressed to any depth and the soil through which the farmer drives the plow is very little altered from the original bowlder clay. On the steeper slopes any loose material is readily washed into the hollows by the rains, so that between and in the lower slopes of the hills is usually accumulated a layer of dark sandy loam containing only the smallest pebbles and having a high percentage of calcium carbonate. Some of the knolls are composed almost entirely of gravel and bowlders, and it is not unusual to see several of them within the scope of a single view, with summits almost completely barren of vegetation of any kind. Where the material is the true bowlder clay, it is so much more compact than the Iowan drift that the tendency is rather to shed the water falling upon it than to absorb it. Plant roots likewise find difficulty in penetrating to any depth, but it is here that the tools of agriculture should intervene as a valuable aid to the natural agents. By stirring deeply, the earth becomes aerated, water readily soaks in and plants extend their roots downward without opposition.

The only serious obstacles to the farmer are the numerous bowlders encountered both below, and at the drift surface. Experience has, however, shown that by perseverance these may be effectually removed and and it is not an extraordinary spectacle to see heaps of them gracing fence corners or lined along the public highway. They vary in size from a few inches to several feet in diameter, and in weight from one or two pounds to a number of tons.

It may be interesting to note an advantage the farmers of Iowa, or the farmers of any region covered with glacial

deposits, have over those who live on soils derived alone from the underlying country rock. The material brought down by the flowing ice is a mixture of earth and rock fragments gathered from over a large area measured in latitude by the distance from the point of accumulation in the frigid north, southward to the place of deposition. It is composed of all species of rocks from the hard crystalline granites, greenstones and porphyries, to the finely ground rock meal of the softer limestone. Thus when disintegration of these bits begins, each yields slowly its characteristic product which contributes something necessary to plant life. By these contributions from innumerable decaying pieces of rock all the elements which are essential to the growth of different crops and which the process of continuous cultivation tends to take away from the soil, are supplied. Each year something is added to the soil by such continuous decay, and it is due to this that bowlder clay soils usually have a remarkable endurance to repeated cropping without becoming exhausted, as is often the case with residual soils. Should successive crops of the same grain tend to decrease the fertility, it is only necessary to practice rotation of crops for a few years, and thus, through rock decay and modification of the clay subsoil the degenerated soil becomes again enriched with the exhausted constituents.

In this way may probably be explained the state of affairs that has existed for the last few years over northern Iowa with regard to the cultivation of wheat. When the wild prairie soil was first tilled enormous crops of wheat were grown yearly, and the farmer relied much upon the yield of this cereal. After a series of years of repeated cropping the yield began to fall off until the wheat crop could no longer be depended on to supply even domestic needs. The soil was undoubtedly overtaxed, and some of the elements necessary to the growth of wheat exhausted. In distinction from the other cereals wheat requires a larger proportion of the element phosphorus, and as compounds of this substance

are relatively scarce in the soil-forming rocks, it is probably owing to the partial exhaustion of this element in an available form that the folling off of wheat production is due. After resting the soil for several years, thus allowing a recuperation of its lost constituents, wheat may be planted with reasonable hopes of an average crop.

The soil developed within the valley of Lime creek contains much sand and is much more susceptible to drought than the upland soils. This may in part be due to its sandy nature, but more to the perfect under-drainage through the Buchanan gravels which underlie the upper terrace.

BUILDING STONES.

Limestone is quarried at several points along Shell Rock river, as has been mentioned under Cedar Valley limestone. The amount removed is limited by a very small local demand, and this local demand is usually determined principally by wants of the owner, upon whose territory the quarry is located. The time is just lately passed when the outcropping ledges along the banks of Lime creek and Shell Rock river were public property, and every one was free to "baul his few loads of stone" whenever occasion demanded. The almost universal advent of the barbed wire fence has, perhaps, accomplished more towards doing away with this friendly traffic than any other factor, but it is at present only necessary to gain permission to enter a neighbor's field or pasture, the latter granting for little or nothing the use of his private quarry. Practically all of the limestone is taken out from the compact, light-colored stratum, and from the underlying, dark magnesian layer as given in the sections along the Shell Rock. The former is a very poor building material because of the serious effects of weathering upon it, especially the action of frost. This may be observed in quarry faces where the cracked and fissured character of this stone stands in contrast with the unweathered dolomite. The non-elastic property of the white limestone, together with its hardness, which is

somewhat above the average, recommend it for road material and concrete. The dolomite referred to is the equivalent of the Mason City dolomite, which is considered one of the best and most durable building stones taken from any of the several quarries in the Cedar Valley limestone of Cerro Gordo county. This has been utilized to some extent in Worth county, the largest exposure being in the northern part of Lincoln township, where the Great Western railroad crosses the river. There are here exposed ten to twelve feet of dolomite of the same character as that quarried in Cerro Gordo county. These beds have been worked intermittently and only a small amount of stone has been taken out.

Obviously the hindrance to more extensive quarry operations in Worth county has been the lack of proper facilities for transportation. Team hauling has been the only method of conveyance, and little of this stone ever finds its way more than a few miles from the place quarried. The excellent character of the stone and the small amount of stripping necessary, on account of the extremely thin sheet of drift along Shell Rock river, are both favorable conditions to the development of the quarry industry. Considering the proximity of the Great Western railroad in northeastern Lincoln township to one of the best rock exposures in the county, it would seem that here are conditions very favorable to the working of these quarries.

These limestones both produce an excellent quality of lime, as they have been used in its manufacture at Mason City in Cerro Gordo county. The dolomitic limestone gives a higher grade of lime than the purer varieties. This magnesian lime does not air slack readily and for this reason may be shipped long distances from the place of manufacture without suffering deterioration. In this branch of the quarry business, Worth county has facilities equal to any of its neighboring counties. A small amount of capital applied under competent supervision would do much to develop these resources at present lying dormant.

The greater portion of the building stone is derived from the igneous rocks of the drift. These are almost universally employed in the western half of the county in constructing walls for houses, barns and outbuildings. The process of splitting these so-called "hard heads" into blocks of desirable shape seems to be an art in which only those who have grown old at this sort of masonry are skilled. In breaking the larger bowlders, a stone drill and blasting powder or dynamite are made use of. When broken sufficiently small to be transported they are moved to the place where the wall is to be built, where further shaping into rectangular blocks is done with the ordinary stone hammer and chisel. Although requiring more work in dressing than limestone, where the latter is not readily available, the extra expenditure of labor is compensated for by the greater durability and the much more comely appearance. The blending of different shades and the contrast between colors in a wall of these hard crystalline rocks present an aspect very pleasing to the eye of those unused to beholding these species in larger masses than our prairie bowlders. The supply of these rocks is practically unlimited, and those at the surface are yearly being added to by bowlders heaved upwards by the frost. The great ice sheets have been the means of laying at our doors free of all charges this material for which importation would be very expensive.

PEAT.

Bodies of peat are accumulating in many of the pondy depressions of the Wisconsin drift. These deposits are continually increasing by the growth of certain species of mosses and the vegetal remains brought in by the wind and water. Although of value as a fertilizer, and in some localities used for fuel, the peat bogs in Worth county are generally regarded as impediments to agricultural progress and much is being done to eliminate them.

WATER SUPPLIES.

The county is well provided with a supply of potable water. In the western part of the county it is drawn almost exclusively from the beds of sand and gravel of the Pleistocene. These furnish a sufficient amount for stock and farm purposes. A goodly, and in many cases quite constant, supply is often obtained by sinking shallow wells into the clay at the edges of glacial ponds or peat marshes. This water is usually contaminated and is used for live stock principally. Wells on the gravel terrace of Lime creek in some cases are sufficiently supplied from these gravels, but quite often it is necessary to go below the level of Lime creek into the underlying limestone.

Along Shell Rock river, and over most of the eastern part of the county, the indurated rocks are generally penetrated to some depth for water. The aquifer is some member of the magnesian strata below those exposed along Shell Rock. Small springs frequently occur, issuing generally at the rock surface, and it is from this source that Mad creek of western Union township is almost entirely supplied. Northwood draws the city supply of water from the base of the Pleistocene deposits, which are here between thirty and forty feet deep.

WATER POWER.

On the Shell Rock river there are two mills, one at Northwood and one at Foster's mill in the southern part of Union township. The former is situated just inside of the Wisconsin border and has a fall of seven and one-half feet, which, with a seven-foot turbine, is capable of developing seventy horse power. Foster's mill has a head of six feet, and when two forty-inch wheels are employed about fifty horse power can be developed. The average slope of the river is less than seven feet per mile, but the volume of water is usually sufficient to run eight or nine months in the year.

On Lime creek Rhode's mill at Fertile is the only one in operation. This mill has a fall of eleven feet, and can develop seventy horse power. The flow is more constant in Lime creek than in Shell Rock, and during years of ordinary rainfall the mill is idle only during the winter months on account of the ice.

ACKNOWLEDGMENTS.

To those who have materially aided in the collection of data for this report, the writer desires to express his sincere thanks. Especially are acknowledgments due to Mr. H. V. Dwelle, county surveyor; Mr. Mitchell and Mr. A. L. Towne for information concerning the wells of the county; Mr. D. Knowles for the Manly well record; and to Mr. D. Williams, whose intimate knowledge of the surface features of the county was a great help in the present investigation. Above all, is the author indebted to Mr. S. W. Beyer, to whose teaching and influence is due in a great measure any value the report may possess.

BY

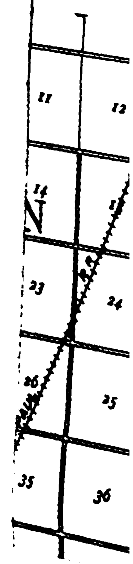
IRA A. WILLIAMS.

1900.

Scale $\frac{1}{125,000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers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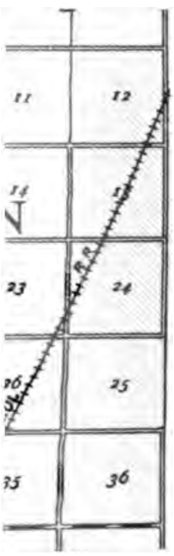
IOWA.

BY

IRA A. WILLIAMS.

1900.



Scale $\frac{1}{125,000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

GEOLOGY OF DUBUQUE COUNTY.

BY

SAMUEL CALVIN AND H. F. BAIN.

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INTRODUCTION.

LOCATION AND AREA.

From many standpoints Dubuque is one of the most important counties in Iowa. It was one of the first to be settled, and in the present connection it is to be noted that the early settlers were attracted to it by the mineral wealth of the region. It is to-day one of the richest counties in the state and includes the second largest city. To the geologist the region is of exceptional interest in that it includes portions of the driftless area together with deposits derived from three ice sheets of very different ages. The indurated rocks include an important portion of the Ordovician and Silurian section and are particularly well exposed. The history told by the physiography of the region touches many of the vital points of the recent geology of the interior. To the mining engineer the county offers a considerable variety of deposits. It offers also an opportunity to study the genesis of ores and the methods of their exploitation under exceptionally simple conditions. Lead, zinc, iron, clay goods, lime, building stone and artesian water are all produced, and copper, barytes, ochre, and cement rock occur. The presence of the river, with one north-south and two east-west railways, makes transportation cheap and affords opportunity for the economical development of the agricutural and mineral wealth of the region. The nearness of the mines to important smelting centers, to the coal fields and to the leading markets, afford an exceptional chance for the development of mineral properties.

In area, Dubuque county includes 601 square miles and is divided into eighteen civil townships as shown on the accompanying map. The eastern and a portion of the northern border of the county is formed by the Mississippi river, which separates it from Wisconsin and Illinois, the dividing line between which cuts the river opposite the city of Dubuque. South of Dubuque county lie Jackson and Jones, while to the west is Delaware and to the north is Clayton.

PREVIOUS GEOLOGICAL WORK.

The presence of important ore deposits in the region early attracted attention to it, and, as is detailed elsewhere, many geologists have visited the region. In a general way it may be said that there was, first, a period of discovery and exploration running from 1750 to 1838; second, a period of early geological work from 1839 to about 1860; third, a period of later geological work from 1870 to 1880; and fourth, a period of recent investigation from 1890 to date. To the first period belong the expeditions of Le Seuer, Pike, Schoolcraft, Nicollet and Featherstonhaugh. These did little except exploratory work and left no geological notes of permanent value. To the second period belong the researches of Owen, Percival, Hall and Whitney, with their assistants. In this period the area was defined, the formations differentiated and the correct theory of the genesis of the ores first foreshadowed. To the third period belong the activities of the second Wisconsin survey, with the work especially of Strong and Chamberlin. This was the beginning of detailed work in the region. To the last period belong the numerous recent studies of the region, made especially with a view to the deposits of zinc, and as a result of the recent increasing use of that metal. In another place in this report the separate papers of the various individuals who have visited the region are noted, and the development of the knowledge of the geology of the region and of the ore deposits is discussed.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Dubuque county may conveniently be considered under three heads, (1) the topography of the driftless area, (2) the topography of the loess-Kansan area, and (3) the topography of the Iowan areas. Under each of the three divisions of the topic many minor divisions might be made. The most striking topographic forms of the county are those of the driftless area, for the boundaries of which the reader is referred to the accompanying Pleistocene map. Within this area the surface inequalities are much greater than elsewhere. Here is a land of deep river valleys cut in the indurated rocks, a land of gorges associated with picturesque bluffs, a land characterized by prominent crags, isolated towers and steep rocky cliffs. With the exception of some conspicuous terraces and ridges of sand and gravel belonging to late Wisconsin age, all the prominent topographic features of the region have been developed by erosion acting upon rocks of varying degrees of hardness. The channel of the Mississippi, one of the dominating and most important topographic features of this whole region, is walled in by bluffs which rise to a height of 300 feet, and from the summit of the bluffs the surface slopes more gradually in places to a height of 200 or 300 feet more. The difference in elevation between the Peru bottoms and the top of Sherrill mound, for example, is about 600 feet. The Little Maquoketa, which, in Dubuque county, is the largest tributary of the Mississippi, in the central part of Center township flows in a valley 400 feet in depth. As is general in areas in which the surface features have been developed by erosion, the drainage courses divide and re-divide until the whole face of the country is marked by a dendritic system of channels which terminate on the slopes of the main divides in countless, minute, shallow trenches. (Fig. 45.) Between the ultimate branches of the drainage system the surface takes the form of rounded swells or ridges, but these may

be much modified in their curves and outlines by the nature of the materials in which the trenches have been carved. For the topography of the driftless area, while developed by erosion, is modified and controlled to a very large extent by the hardness of the indurated rocks, so much so that each geological formation expresses itself in some form or other, in the characteristics of the surface. Along the whole river front from Waupeton to the southeast corner of Mosalem township, the Galena-Trenton formation gives rise to steep scarps and vertical cliffs which become more pronounced as the dolomitized Galena makes up more of their entire height. Precipices rising sheer for some scores of feet are common features of the landscape wherever erosion has cut into the Galena limestone. Examples of such cliffs are numerous, but those fronting the river near the southeast corner of Julien township, others at the mouth of Catfish creek, and many along the sides of the valley of the Little Maquoketa southwest of Durango will serve as types. The towers (Fig. 46) and castles so common in the eastern part of the county, are topographic features dependent on the manner in which the Galena limestone yields to erosion. Other features produced by unequal waste of this limestone are found in long, narrow, steepsided ridges, eighty to 150 feet in height, blending into the upland plain at one end, and running out in picturesque isolation at the other. They are produced by two nearly parallel erosion channels meeting at a small angle. Such a prominent salient is seen east of the junction of Valley street with Southern avenue, in the lower part of the city of Dubuque. An isolated knob of Galena limestone, 170 feet in height, cut off by the shifting of the channel of Catfish creek, and lying between the mouth of the creek and the valley here followed by the Illinois Central railroad, is one of the interesting phenomena connected with the development of the topography of the driftless area. On this prominent hill of circumdenudation stands the chaste and appropriate monument recently erected over the grave of Julien Dubuque.

No more charming and picturesque spot could possibly be found anywhere. The view from this lofty point commands the river for a number of miles in both directions. The great stream, placid and reposeful when undisturbed by river craft, and dotted with green islands away to the southern horizon, flows with seemingly conscious majesty past the very foot of the rocky cliffs forming the riverward face of the hill. In the middle distance to the eastward is the Illinois flood plain, threaded with channels carrying thin strands of water, and sprinkled with clumps of foliage trees which are richly luxuriant in the vivid greens of spring and early summer, and resplendent with flame and golden tints in autumn. Beyond the flood plain rise the eastern bluffs, and far away on the horizon stands Sinsinewa. Near the grave grows the wild grape vine, perfuming the air in spring, while overhanging oak and linn lend glory to the fall. The wild verbena blooms profusely through the summer season, and the hum of visiting bees makes an indefinite, unobtrusive, restful music, scarcely noticed amid the multitude of impressions which fill the mind of the visitor to this interesting spot with such peculiar delight. On warm summer afternoons the cool shades of the near-by forests ring with the rich, unmatched, melodious piping of the wood thrush, and one might easily fancy that the seclusion which brooded over the hills a full century ago had never been broken. And yet when attention is aroused the rest and seeming seclusion of this charming place is invaded from the north by the jar and mingled discord of all the sounds incident to the commerce and manufactures of a great modern city. If attention be given to the immediate surroundings only, the monument stands in the midst of unaffected nature. The sights and sounds are those which characterized the region at the first visit of the first white man more than a century ago. But within sight and hearing from the crest of the hill has grown up a city which perpetuates the name of the first miner who systematically worked the crevices of the Galena limestone for ores of lead. Much of the interest

and picturesque charm of the locality depend on topographic features made possible only by the characteristics of the Galena limestone. Blocks of Galena limestone form the graceful monument beneath which he sleeps. Could more appropriate surroundings be chosen for the last resting place of Julien Dubuque?

The Maquoketa shales overlying the Galena, which will be discussed under the head of stratigraphy, are soft, easily eroded, and give rise to a very characteristic topography. In the region occupied by the shales the land forms are not so rugged and angular as those formed by the Galena, the curves are more flattened and regularly rounded, the slopes are more gentle. (Fig. 50.) The surface of the Maquoketa area is not developed into a plain; it is far from having a uniform slope; toward the west where the Maquoketa area joins the Niagara the surface may rise at a relatively high angle; toward the eastern edge of this area, the surface, as a whole, shows a tendency to become more horizontal. Furthermore, the summits of the minor ridges, even when a very limited area is considered, do not all rise to the same altitude. There is a certain tumultuousness and irregularity about the surface, even of those areas where there is, on the whole, a tendency toward a general leveling, which clearly distinguishes the region dominated by the shales from that of the loess-Kansan, where the surface features are somewhat similar, but developed by comparatively recent erosion in a sheet of loose drift. Except in the immediate neighborhood of the drainage courses, the surface of the Maquoketa area is level enough to admit of cultivation.

The Maquoketa shales are overlain by the hard magnesian limestone called the Niagara. The influence of the Niagara limestone on the topography of the county is even more marked than that of the Galena-Trenton. It is masses of Niagara limestone which form Sherrill mound and other smaller mounds in the same neighborhood. Table mound is the end of a narrow ridge reaching out like a promontory or

rocky headland from the general Niagara area. Table mound is in fact a part of what, looking from the east, seems to be a continuous line of hills setting off the imperfect plain which begins at the summit of the Mississippi bluffs, from the higher table land occupying all the rest of the county to the westward. The hills are simply a line of steep slopes, sixty to a hundred and fifty feet in height, coincident with the eastern outcropping edge of a heavy body of Niagara limestone. This line of hills, very appropriately, has been called by McGee the Niagara escarpment. Traced on the ground it is found to wind back and forth to form the rims of sinuous, branching valleys, running back into the interior of the county for many miles, and projecting in digit-like extensions toward the larger valleys on the summits of the primary and secondary divides. Altogether it forms one of the most striking and one of the most generally recognized topographic features in the entire state of Iowa. It marks the present position of the edge of the Niagara limestone, but its position is not constant. Owing to continual waste under the effects of weather, the escarpment is slowly receding, and the area eastward to the river, and that east of the river to corresponding mounds and escarpments in Wisconsin and Illinois, are simply a measure of the extent to which the Niagara limestone has been removed from the surface by the erosion of the gorge of the Mississippi and its tributary valleys. Only the forms developed in the deeply gashed and eroded edge of the Niagara limestone are to be included in the topography of the driftless area; for while the margin of the loess-Kansan area does not coincide with the Niagara escarpment, the Kansan drift plain, with its special topographic types, does begin not very far to the westward.

Among the many interesting topographic features of the driftless area, there is none more striking than the Couler valley, a deserted river channel some five miles long, connecting the Little Maquoketa valley at Sageville with the Mississippi at Dubuque. This valley is a sharp walled canyon

nearly 200 feet deep and about a half mile wide, with flat alluvial bottom. The northern portion is used by a small branch flowing into the Maquoketa, while Couler creek flows down the valley and through Dubuque to the Mississippi. There is no col and no divide proper. The valley is open and drains both ways. In time of very high water the Maquoketa still uses it for a portion of its flood. For example, in 1853 water passed through the valley, and at present its proper drainage forms a considerable problem. Couler valley connects with the Maquoketa valley a little more than a mile above the point where the latter opens out on the Mississippi bottom lands. The waters of the Maquoketa find their way into the Mississippi by traveling about two miles northeast from Sageville. By following the Couler valley they might, in five miles, find their way into the Mississippi some seven miles below the point at which they actually join it. They travel by a route which is, roughly, four miles longer than the one which has been deserted. The change has thus resulted in lengthening the course of the stream, and also in so diverting the tributary as to cause it to join the main stream higher rather than lower. Such a change requires especial explanation.

So far as can be learned there is no obstruction in Couler valley to account for the diversion of the stream. Such wells as are on record show a deep filling of the valley here, the same as along the Mississippi. As the locality is far outside the limits of the glacial action, the change cannot be referred to the agency of ice. Though the valley is crossed nearly at right angles by the Eagle Point anticline, there is no evidence connecting the rise of the latter with the diversion of the stream. In short, the explanation seems to be in the ordinary process of stream capture. From Sageville to the Mississippi by the present route is a shorter distance than by the old one, so that assuming that the Mississippi were at the same level at the two exits, the new route would have much the steeper grade, and a stream working along it would have the advantage over

one flowing through Couler valley, and would in time capture the Maquoketa. The Mississippi has so slight a fall that practically the above supposed set of conditions obtain, and while the present course of the waters is the longer one, the greater volume of water in that portion of the course made up by the Mississippi compensates for the added distance, and enables the river to hold to its new course.

It is probable, too, that the situation of the mouth of the Maquoketa at a point where the Mississippi, for a long time, evidently cut against its western bank, was an efficient factor in promoting the change. That the change was a slow one, and that the river probably shifted several times before settling to its present course, is indicated by the anomalous topography where Bloody Run joins the Maquoketa at Sageville. Bloody Run has evidently shifted its channel to the northeast to accommodate itself to the change in the course of the Maquoketa, and in the process it has abandoned the lower portion of its old channel. The cut used by the Chicago Great Western railway in passing from the Couler to the Maquoketa valley is a col, but it probably does not mark the former main channel. If, however, the Couler valley had continued to be used by the river the latter would, in time, have found its way through this gap.

Another interesting example of stream rearrangement is seen near the mouth of Catfish creek. A few hundred feet north of the present mouth is an old valley now used by the Illinois Central railway and connecting with Catfish valley about a half mile from the river. The stream has evidently shifted its course so as to empty into the Mississippi farther down the main channel. Possibly Grange creek formerly had independent outlet and has captured Catfish.

The date of the rearrangements of the streams is unknown. Apparently they are not recent, and certainly they are pre-Wisconsin, since the terrace gravels of the Wisconsin age occupy new and old valleys alike. If one may judge by the

relative sharpness of the topograpy in the vicinity of the post-Kansan gorge of the Catfish, in Table Mound township, the changes just described are of preglacial age.

It will probably be sufficient here merely to note, as a feature of the topography of the driftless area, the ridges and terraces of Wisconsin gravels, which will be more fully described in a later part of this report under the head of deposits of the Pleistocene.

Leaving out the small lobes of Iowan, the loess-Kansan topography will be found well illustrated in all the remaining parts of the county lying inside the border of the Kansan drift. Where this topography is typically developed the surface is an undulating plain upon which a miniature erosional system of hills and trenches has been developed. The inequalities of the surface have, in general, been carved in the loose materials later described in this report as loess and Kansan drift. Evidences of rock cutting in connection with this phase of erosion are very rare. On the slopes adjacent to the larger drainage courses the water-cut trenches may be twenty, forty, or even sixty feet in depth, with the sides of the ravines steep and the curves all sharp; but there are certain large areas in which the loess-Kansan surface is gently undulating, the water courses being broad, shallow depressions, while the convex curves are low and flat. One of these areas, so far as it belongs to the loess-Kansan province, occupies the northern half of the entire south tier of townships, together with the southern half of Dodge, Taylor, Vernon and Table Mound. Another similar area embraces the western part of Iowa and Concord townships, all but the northwest corner of Liberty, and nearly all of New Wine. The boundaries indicated for these areas are only approximate, the object being simply to give concrete illustrations of a most important type of surface configuration. As fair an illustration, however, of the moderately undulating loess-Kansan plain as can be found anywhere occurs between Peosta and Epworth; while the whole of Washington township, except the southwest corner,

and all of Prairie Creek, except the southeast corner, present the same general type of topography. The moderately eroded loess-Kansan plain, with its subdued relief, is perhaps the most important part of the county from an agricultural point of view. A dark, friable, loamy soil is here developed

FIG. 45. Topography of the driftless area underlain by Maquoketa shales. View taken from top of Table Mound looking north.

on the loess, and farms of easy tilth and generous productiveness at once account for the evidences of comfort, plenty and general prosperity which everywhere abound among the fortunate occupants of such a region. The loess-Kansan area mapped in Dodge township is a somewhat prominent ridge overlooking two low lying lobes of Iowan drift.

The topography of the Iowan lobes is very simple. In general the surface is flat. Whatever inequalities and irregularities it may possess are constructional and not erosional. It is not covered with loess, but is sprinkled with large granite bowlders. The drainage is not as perfect as in the loess-Kansan region. The soil is a very black, rather tenacious, very fertile loam. The level, bowlder-dotted plain upon which the Illinois Central railroad enters west of Farley affords a concrete illustration of the Iowan topography.

Between Dubuque and Peosta the traveler has on all sides the bold topographic forms of the driftless area; from Peosta to Epworth the surface presents the miniature erosional forms of the loess-covered Kansan plain; west of Farley the scene changes suddenly to the new, immature topographic features of the Iowan.

DRAINAGE.

Although the drainage of Dubuque county is controlled by the Mississippi river, the surface of the county is divisible into two main drainage areas which are separated by the rather indefinite ridge marking the border of the Kansan drift. On one side of this dividing line is a driftless area with waters recognizing at once the authority of the master stream and flowing directly towards it. The greater part of this area is covered by two drainage valleys—that of the Little Maquoketa and its many branches, and that drained by the several forks of Catfish creek. The other streams of the driftless area are small and of little importance. Hollow creek in the northwest corner of Liberty township, may be mentioned in connection with the streams of the driftless area; in place of flowing directly toward the Mississippi river this stream flows into a tributary of the Turkey.

The western portion of the county embraces the drift-cov ered areas. Here the drainage courses, beginning in th marginal ridge of the Kansan drift, all trend at first towa the southwest, directly away from the Mississippi rive Lytle creek and Whitewater creek, in Washington and Prair Creek townships, illustrate the general tendency west of th drift margin. These streams are tributary to the Nort Maquoketa, which, beginning in Liberty township with t southwest trend common to the drainage of this region, pass from Dubuque into Delaware county south of Dyersville, aft which it changes its course to the southeast, traverses t southwest corner of Cascade township and receives the su plus waters from the southern portion of the drift-plains


MISSISSIPPI
RIVER
CHICAGO
MILWAUKEE
Rockdale
Key West

the county. The Little Maquoketa has backed up so as to capture a small part of the drainage from the drift-covered area. Whatever the cause, it is true that the general trend of the drainage in the two principal areas is in directly opposite directions, and approximately at right angles to the drift margin.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

The geological formations of Dubuque county are of unusual interest, and, compared with other counties in Iowa, they are more than the average in number. The deep erosion to which the driftless area, occupying the eastern part of the county, has been subjected has cut down through one formation after another, so as to give continuous vertical sections of three to four hundred feet in thickness. Satisfactory exposures are multiplied by the score in every gorge and valley of the driftless region; some of the most instructive being found almost in continuous sequence from one end of the county to the other, along the picturesque bluffs of the Mississippi river. On account of the great amount of rock erosion in the driftless area, and owing to the absence of the drift mantle which, over the greater part of Iowa, effectually conceals the indurated rocks, the geological structure of Dubuque county lies open to the observer in a way unknown in the drift-covered portions of the state. Excepting the valley of Hollow creek —Pine Hollow, as it is frequently called—in the northwest corner of Liberty township, the western part of the county is covered with drift; and since no deep valleys have been excavated since the deposition of the drift, the comparatively few rock exposures of this region all belong to a single formation.

The general relations of the geological strata of Dubuque county are expressed in the following synoptical table. In studying the table, however, the reader will please bear in mind that while some of the names in the last column are names of recognized geological stages, the authors have taken

the liberty, especially in the Pleistocene, to use formational names having neither uniform nor co-ordinate taxonomic value.

SYNOPTICAL TABLE

SHOWING TAXONOMIC RELATIONS OF GEOLOGICAL FORMATIONS IN DUBUQUE COUNTY.

GROUP.	SYSTEM.	SERIES.	FORMATION.
Cenozoic.	Pleistocene or Quaternary.	Recent.	Alluvium.
		Glacial.	Wisconsin Terraces.
			Iowan Drift.
			Loess
			Buchanan Gravels.
			Kansan Drift.
			Residual Products.
Paleozoic.	Silurian.	Niagara.	Delaware.
	Ordovician.	Trenton.	Maquoketa.
			Galena.
			Trenton.
		Canadian.	Saint Peter.

So far as known there are but two systems of indurated rocks, the Ordovician and the Silurian, represented in Dubuque county. The Rockville conglomerate, provisionally referred to the Cretaceous system by McGee,* occurs in Delaware county, near Rockville, within three-fourths of a mile of the Dubuque county line; but no exposures of this formation were observed in the county now under consideration. The conglomerate, where known, occurs in small, detached patches which might very easily be overlooked.

*Pleistocene History of Northeastern Iowa, by W J McGee; Eleventh An. Rept. U. S. Geol. Surv., pp. 234, 307, 308. See also Report on Delaware county, by Samuel Calvin; Rept. of Iowa Geol. Surv., Vol. VIII, pp. 160, 161.

On Table mound, and possibly on other high points in the county, are traces of a gravel corresponding in all essential particulars to that described by Professor Salisbury from the Devil's Lake region of Wisconsin.† This gravel consists of chert and quartzose material, thoroughly rounded, and, while the relations are not thoroughly clear, it seems best to refer it to pre-glacial agencies. In its presence here and on Iron Hill, near Waukon,‡ it shows a habit similar to that observed in Wisconsin. That it is found on the high points only seems to indicate a former extension over the whole region at a period anterior to the valley cutting. Its age cannot be more definitely asserted until a fuller study of the gravels of the whole region shall have been made. Such a study would doubtless clear up much of the pre-Pleistocene history of the region and allow the drawing of some inferences of value as to the age of the drainage.

From both the commercial and the scientific point of view the beds in this county belonging to the Ordovician are more important than those belonging to the Silurian. The Ordovician formations are found in the eastern part of the county, in the area of deep rock erosion, in the area where the drift mantle was not deposited, the area where the indurated rocks are not concealed, except so far as they are hidden by the thin and frequently interrupted accumulation of loess and residual clays. By far the greater number of the rock exposures in the county, therefore, belong to one or the other of the Ordovician series. The Ordovician presents a larger number of distinct formations than the Silurian, and a correspondingly larger number of interesting geological problems; while the single formation known to geologists as the Galena limestone, with its unexcelled material for lime burning, its quarry products suitable for massive and other forms of masonry, and its immense deposits of the ores of lead and zinc, and occasional beds of iron, gives to the Ordovician a commercial importance unapproached by any other system in

‡Iowa Geol. Survey, Vol. IV, p. 85.
†Jour. Geol., Vol. III, pp. 655-667.

Iowa, except the Carboniferous. The other Ordovician formations are not devoid of interest from any point of view.

ORDOVICIAN SYSTEM.

SAINT PETER SANDSTONE.

The oldest geological formation found in Dubuque county is the Saint Peter sandstone. It is exposed at a number of points along the Mississippi bluffs, from a mile or two above Specht Ferry to Zollicoffer lake, a distance of five or six miles. The strata forming the section seen in these bluffs are thrown into a series of gentle folds which cause the sandstone in places to appear above the railway track that here follows the river, and in places to dip below it. At Specht Ferry the top of the Saint Peter is seen near the railway station and nearly on a level with its platform. Three-fourths of a mile above the station a small syncline depresses the top of the sandstone ten feet below the level of the track, while one-fourth of a mile farther up the river the sandstone ascends a few feet above the bed of the railway. Maintaining this level for some distance, it again descends, and is not afterward seen in this direction in Dubuque county.

From one-half to three-fourths of a mile below Specht Station there are good exposures of the Saint Peter, showing the upper five feet of the formation above the bed of the railroad, and from twenty-five to thirty feet above the level of the river. The sandstone is here somewhat definitely bedded, being divided into a few comparatively thin ledges. Farther north, in Clayton and Allamakee counties, where this formation is exposed throughout its whole thickness, bedding planes are few; indeed in places it would seem as if the sand had been deposited continuously so as to form one undivided stratum. The sandstone appears at intervals in following down the river, the points of appearance coinciding with the axes of anticlinal folds. The last appearance noticed was

opposite the middle of Zollicoffer lake, where a single undivided ledge, six feet in thickness, rises above the grade of the railway.

The Saint Peter sandstone, as seen in Dubuque county, is rather ferruginous, and it is very generally stained in varying shades of red and brown and yellow. The colors are dull and dingy, as a rule, in marked contrast with the clean, clear whites and the bright reds and other tones which lend such pleasing variety to sections of this formation when the main body of it is exposed. The coloration of this sandstone in Dubuque county is due to infiltration from above, as the overlying Trenton limestone is wasted by the solvent action of air and water, and contributes its contained iron, in oxidized condition, to discolor the pure, white quartz sand which normally makes up the Saint Peter formation. Owing to its greater insolubility the Saint Peter recedes in bluffs and hillsides more slowly than the Trenton, so that it is common to find a bench or terrace of the sandstone projecting beyond the foot of the cliffs of limestone. It is the upper layers of this bench that are discolored by the descending waters which carry various waste products of the limestone in solution.

As to texture, the sandstone is coarse; it is more or less friable. In the normal condition, as seen where it is more completely exposed, the sand grains have about as little cohesion as when they were originally laid down in the Ordovician seas. The upper five or six feet—the only part of the natural exposures of this formation in Dubuque county left unconcealed by railway embankments and talus slopes—have been cemented to a greater or less degree by the iron and calcareous salts carried from the overlying limestone and deposited from solution in the interstitial spaces of the sandstone. The resulting consolidation has made it possible, in some cases, to use the Saint Peter as quarry stone. At Specht Ferry there is a large, two-story building, eighty by thirty feet on the ground, constructed of blocks quarried from

this formation and bearing evidence of the skill of the professional stone-cutter. So far as known to the writers this is the most pretentious structure in Iowa made from the Saint Peter sandstone.

In this county the Saint Peter sandstone contains no organic remains. At all events, no fossils were observed. The formation is very generally unfossiliferous. The conditions under which such a bed of sandstone could accumulate would make life on the sea bottom well nigh impossible; but even if the seas of the age had swarmed with life, it is extremely improbable that any traces of it would be preserved. For what is known of the fauna of the Saint Peter sandstone the reader is referred to Volume IV of the present series of reports, pages 72 and 73.

TRENTON LIMESTONE.

The Saint Peter sandstone is followed, apparently conformably so far as this county is concerned, by the formation generally recognized in the west as the Trenton limestone. Hall, in his report on the geology of Iowa, published in 1858, seems to have been the first geologist dealing specifically with Iowa geology, to correlate the strata occupying this horizon with the Trenton limestone of New York. In 1843 Conrad, in the proceedings of the Academy of Natural Science, Philadelphia, published descriptions of fossils found at Mineral Point, Wisconsin, and recognized the fact that they were associated with a fauna characteristic of the New York Trenton. In the first volume of the Paleontology of New York, published in 1847, Hall redescribed Conrad's species, and noted the fact that they occur in blue limestone associated with Trenton limestone fossils. In the earlier report of Owen, published in 1844, and giving an account of geological explorations made in Iowa, Wisconsin and Illinois in the autumn of the year 1839, this formation is named, in figures 5, 6 and 7 of Plate I, the *Blue fossiliferous limestone;* while in his later report on the geology of Wisconsin, Iowa and Minnesota, published in 1852,

Owen describes the formation following the Saint Peter sandstone under the title of the *Saint Peter's Shell limestone.* Hall's example has been very generally followed by later geologists. At all events, some beds immediately overlying the Saint Peter sandstone have been referred to the Trenton by all subsequent writers on western geology when discussing this part of the geological column; but there has been a conspicuous lack of agreement amongst the several writers as to the precise upper limit of the formation in question. Some of the discordant conclusions respecting this subject have evidently arisen from the fact that the problem has generally been approached with what now seems to be an erroneous preconception. It was at first assumed, and quite naturally, too, that the Trenton and Galena limestones are two distinct formations, sharply set off one from the other by a definite plane, or at least by transition beds occupying a definite horizon. In making discriminations between the two formations it was taken for granted that the Trenton is, as a rule, thin bedded and non-dolomitic, while the Galena is made up of heavy, massive beds, and is uniformly and completely dolomitized. As illustrations of the varying conclusions which have been reached respecting the thickness of the Trenton,—how far above the Saint Peter sandstone the line separating the Trenton from the Galena should be drawn—the following references are instructive. Hall,* in his report on the Geology of Iowa, gives the thickness of the Trenton at Pike's Hill as seventy-five feet, and that without including the "magnesian beds below" (Lower buff beds) in the estimate; at Elkader he makes the thickness twenty-five feet; near Clayton City he reports a thickness of twenty to thirty feet; and in rear of the town of Guttenberg he gives a thickness of 100 feet to the strata between the top of the Saint Peter and the base of the Galena. White,† writing of the Trenton limestone, says: "The thickness of this formation as seen along

*Geological Survey of Iowa, by James Hall, 1858, Vol. I, Part I, pp. 54-59.
†Geological Survey of Iowa, by Charles A. White, 1870, Vol. I, p. 175.

the bluffs of the Mississippi is about eighty feet, but in Winneshiek county we find the thickness increased to upwards of 200 feet." Both Hall and White treat the Galena limestone as an independent formation having definite characteristics, vertical dimensions, and geological position of its own. In the reports of the Geological Survey of Illinois, conducted by Worthen, there are references in Volumes I, V and VII to the Trenton limestone as it occurs in parts of the state adjacent to Iowa. The Galena and Trenton are usually treated together under the name of the Trenton group, the intimate relations of the two formations being thus recognized; but it is still assumed, though not expressly stated, that the lead-bearing Galena is separated by a definite formational plane from the blue and buff divisions, which are usually correlated with the New York Trenton. Worthen divides his Trenton group into three divisions, as follows:

	FEET.
Galena, or lead-bearing limestone	250 to 300
Thin bedded, bluish-gray limestone (glass rock in part)	50 to 75
Buff and brown magnesian limestone	20 to 30*

Under the name of the Trenton group Chamberlain† very properly combines the Trenton and Galena limestones and the Cincinnati (Maquoketa) shales. The Trenton and Galena are treated separately, and the Trenton is divided into four members, as follows:

	FEET.
Upper blue beds	15
Upper buff beds	55
Lower blue beds	25
Lower buff beds	25

This gives 120 feet between the top of the Saint Peter sandstone and the base of the recognized Galena. Worthen measures 100 feet of strata between the same limits. White recognizes a variation of from 80 to more than 200 feet, and Hall's measurements of the beds belonging to this position range

*Geological Survey of Illinois, Vol. I, 1866, p. 141.
†Geology of Wisconsin, survey of 1873-1877, Vol. II, p. 290 *et seq.*

from 20 to 100 feet. In the fourth volume of the present series of reports of the Iowa Geological Survey, in the report on Allamakee county, Calvin estimates that there is something more than 250 feet of limestones and shales between the Saint Peter sandstone and the dolomitized Galena. McGee's description of the Trenton of Iowa* embraces the following statement: "The richly fossiliferous limestones of this formation are moderately pure, heavily bedded, and nearly free from argillaceous matter in the southernmost exposures, where the mass is perhaps seventy-five feet in thickness; but northwestward the body thickens rapidly and becomes shaly, particularly in its upper portion—its thickness in northern Winneshiek county reaching not less than 250 and perhaps 350 feet." On the other hand N. H. Winchell limits the application of the term Trenton limestone to the calcareous beds lying between the Saint Peter and the horizon of green shales which seem to occur everywhere in the Mississippi valley not very far above the base of the Trenton. In Allamakee and Dubuque counties, where these formations have been most carefully studied in Iowa, the green shales of the Minnesota geologists are found from forty to fifty feet above the top of the Saint Peter sandstone. The beds intervening between the Saint Peter and the green shales must be thinner in Minnesota; for Winchell, describing the Trenton of Houston county, says:† "This formation, as known in Houston county, consists of limestone layers that amount to a thickness of not more than fifteen feet. These layers are overlain by beds of shale and fossiliferous shaly limestone which reach an unascertained thickness, but probably not exceeding twenty-five feet. These shaly beds have been denominated "Green shales" in the reports of progress of the survey, but they seem to belong to the Hudson river age of New York. They are overlain in Fillmore county, and in northeastern Iowa, by firm calcareous strata which attain a thickness of fifty or

*Pleistocene History of Northeastern Iowa; Eleventh An. Rept. U. S Geol. Surv., p. 329. Washington. 1891.

†The Geology of Minnesota, Vol. I, of the Final Report, p. 318, 1884.

sixty feet, which seem to fade into the Galena formation of Iowa." In the report on Fillmore county* the "green shales" are assumed to belong to the Hudson River group of New York, and the further statement is made that "if any designation besides Hudson River be needed, the term Galena may include all the calcareous strata above the green shales belonging to the Lower Silurian."

Later, however, as a result of careful paleontological studies, Winchell was led to modify the view he had entertained respecting the position of the "green shales" and the overlying calcareous strata which he had correlated with the Galena, the view,—namely, that "there is reason to include them all in the Hudson River epoch."* In his paper† on the age of the Galena limestone, in the *American Geologist* for January, 1895, he concludes, after an exhaustive examination and analysis of the faunas of the formations under consideration, that there is a close alliance of the Galena with the Trenton; that the Galena changes gradually to the north by acquiring shale; that paleontologically it has no downward limitation; that in fact the Galena is only a phase of the Trenton, intensified in the typical region, and fading out in all directions; and that the physical break and the faunal change which follow it, in the northwest, are the probable parallels of those which mark the transition from the Trenton to the Hudson river.

Norton, in his memoir on the artesian wells of Iowa,‡ expresses the view, suggested by an examination of well records, and tentatively entertained by members of this Survey on the basis of studies in the field, that the difference between the Galena and Lower Trenton is merely lithological and not formational. He regards it as very probable that the strata included under the names of Galena and Trenton are one formation which varies locally in the extent to which dol-

*Op. cit., pp. 289 and 293.

*Op. cit., p. 289.

†American Geologist, Vol. XV, p. 33. Minneapolis, 1895.

‡Artesian Wells of Iowa, by William Harmon Norton, Rept. Iowa Geol. Sur., Vol. VI, p. 146. Des Moines, 1897. See also Plate vi, opposite page 139.

omitization has taken place; and this single formation he discusses under the name of Galena-Trenton. Further study he thinks, however, is desirable, and he says: "To demonstrate their formational identity it will be necessary to trace through both the same life zones, and this may be left in confidence to future work in the field."

The above references, showing estimates of thickness for the Trenton, as it was at first recognized, ranging all the way from fifteen to 350 feet, and the later tendency to unite the so-called Trenton and Galena under one formational name, sufficiently illustrate the discordant views which have been held and expressed respecting the limits to be assigned to the Trenton limestone and the significance which should be attached to the term, as the formation is developed in the valley of the Mississippi river. It may not be possible to reconcile all these differences of opinion, though it would not be difficult to point out how, in the most natural way, they have originated. Some facts developed by later studies of the Galena-Trenton of Iowa confirm the opinion that the two supposed formations, at least as these formations have been recognized by the geologists of Iowa, Wisconsin, and Illinois, constitute one geological unit. This unit varies somewhat in thickness in different localities; it varies locally as to the amount of argillaceous matter which it contains; but its chief variation, and that which more than anything else has led to the discrepant opinions that have just been noted, lies in the extent to which it has been altered by the process of dolomitization. It may safely be assumed that, aside from the shaly portions, the material originally composing the formation was calcium carbonate derived from the disintegration organic skeletons; and that in certain parts of the geologic basin the calcareous beds, or some limited portions of them, were altered to dolomites. The process of dolomitization was more complete in some portions of the basin than in others, and affected the strata through a much greater thickness. As a result of the alteration, bedding planes were obliterated where

the layers were not separated by bands of shale, and thus the massive ledges which we now recognize as characteristic of the Galena, were produced. Traces of fossils were, to a very large extent, blotted out; this being particularly true of brachiopod shells and other forms which blended homogeneously with the matrix. In Iowa, Wisconsin, and Illinois the dolomitized portion of the formation has been called the Galena limestone; while most geologists have been calling the non-dolomitized portion, no matter what its thickness or what life zones it may happen to embrace, the Trenton.

The alteration of the original limestone was more complete, and descended further toward the bottom of the formation in the vicinity of Dubuque than anywhere else in Iowa. Accordingly it is at Dubuque that the Galena limestone part of the formation is thicker, and the typical Trenton correspondingly thinner, than in such localities as Winneshiek and Allamakee. In the counties last named dolomitization affected comparatively few layers, and these are in the upper part of the formation; the greater part remains but little or not at all changed, and hence the surprising thickness of the so-called Trenton reported from this part of the state.

In support of the view that the Galena-Trenton represents but a single formation which has suffered more alteration in certain localities than in others, the following facts are noted: The combined thickness of the two alleged formations remains nearly constant. Where the Trenton limestone is greatly thickened, as in the northern part of the state, the Galena limestone is thin; while at Dubuque the great thickening of the Galena is accompanied by the greatest attenuation of the Trenton. The "green shales" of the Minnesota geologists constitute a well marked and constant horizon, characterized by a distinct fauna, of which *Orthis* (*Dalmanella*) *subæquata* Conrad, and *Orthis tricenaria* Conrad, are diagnostic species. At all events, if these two species of Orthis are not strictly limited to the green shales, their range is confined to a very narrow zone in this part of the geological column. In Iowa

the bed of shales containing the species named lies practically parallel with the base of the Trenton, between forty and fifty feet above the top of the Saint Peter sandstone. Now, in Allamakee and Winneshiek counties the dolomitized Galena begins more than 200 feet above the *Orthis subæquata* horizon; while at the Eagle Point Lime Works, in Dubuque, heavy bedded dolomite (Galena) begins directly on top of the green shales, carrying *O. subæquata*, *O. tricenaria* and associated species of the green shales fauna, and not more than sixty or sixty-five feet above the upper surface of the Saint Peter sandstone; which rises to view about five miles up the river, at Zollicoffer lake. Some hundreds of feet of strata, which are non-dolomitic and have been referred to the Trenton in Allamakee and Winneshiek, are completely dolomitized and assigned to the Galena in Dubuque. There are well defined life zones in the so-called Trenton of the northern counties, which have their counterparts at the same distance above the Saint Peter in the Galena. For example, along the Yellow river, in Allamakee county, there is a zone, ten or fifteen feet in thickness, carrying a gastropod fauna which embraces *Maclurea bigsbyi* Hall, *Maclurina cuneata* Whitfield, *Murchisonia* (*Hormotoma?*) *bellicincta* Hall, *M.* (*H.?*) *major* H., *Fusispira elongata* H., and *F. inflata* Meek & Worthen. In the northern counties the beds carrying this fauna, and superincumbent beds to a thickness of seventy or seventy-five feet, have always been referred in Iowa to the Trenton; but this same fauna occurs in the Galena limestone at Dubuque, and its place in the geological column is the same as in Allamakee county, namely, from 200 to 220 feet above the base of the Trenton, or from 80 to 100 feet below the contact of the Galena with the overlying Maquoketa shales. Another life zone equally persistent and equally significant, is that of *Receptaculites oweni* Hall. This species has been supposed to be especially characteristic of the Galena. It ranges through 100 or 120 feet of the formation, but specimens are rare, except in a band about ten feet in thickness and sixty feet below the

contact with the Maquoketa. This is the true Receptaculites zone. At this horizon the puzzling and curious disks are numerous and fairly crowded together. Furthermore, the horizon is constant and easily recognized throughout the Dubuque district. Studies outside the district, however, show that the same zone, characterized by the great development of this same species of Receptaculites, is found in the same geological relations in non-dolomitized beds which have been counted as typical Trenton. The Galena-Trenton is one formation which in some way, at present not well understood, has had the original calcareous beds changed to dolomite to a much greater extent and through a much greater thickness in some localities than in others. As above stated, the unchanged beds have been called Trenton, the dolomitic beds Galena; and the apparently irreconcilable statements concerning the thickness of the respective assumed formations have been due to the preconception that the whole of the Galena overlies the whole of the Trenton, with a definite formational or stratigraphic plane of separation between them. Instead, a large part of the Galena near Dubuque is the exact equivalent, bed for bed, of a correspondingly large part of the Trenton in northern Iowa. Bands characterized by distinct types of life, run parallel and continuously through dolomite in one place and unaltered limestone in another. The relations of the two formations are illustrated in Plate No. 2. The line of separation is not formational; it pays no regard to stratigraphic planes, except that in places it seems to be determined for some distance by beds of shale; it cuts across individual layers and life zones in the most erratic manner; and while, on the whole, it rises toward the north, it wanders up and down through many feet in very short space, as evidenced by the sections recorded by Hall near Elkader, Clayton City, and Guttenberg in Clayton county.

It looks as if dolomitization had affected the limestone and produced the Galena type after the formation was complete; that the process began at the top and progressed downwards;

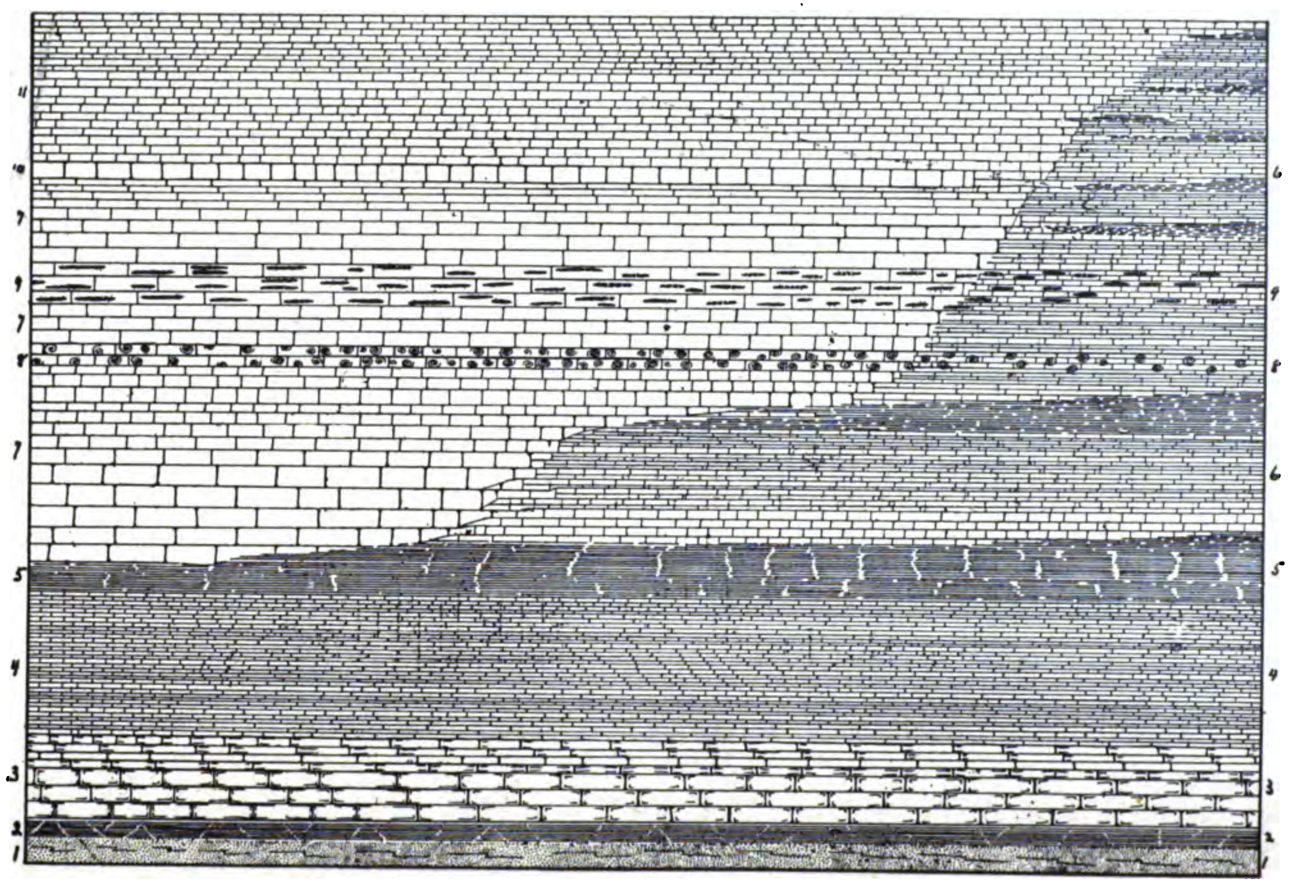

PLATE I. General section showing the relations of the Galena-Trenton; the vertical scale very much exaggerated. 1. Saint Peter sandstone. 2. Basal shale. 3. Lower Buff beds. 4. Thin, non-magnesian beds equivalent to Nos. 3, 4 and 5 of the Specht Ferry section. 5. "Green shales," equal to No. 6 at Specht Ferry. 8. Gastropod horizon. 9. Receptaculites beds.

and that the depth to which the change descended was, in some instances and to some extent at least, determined by the presence or absence of impervious beds of shale. It has been already noted that at Eagle Point the Galena begins immediately above the "green shales" of Minnesota—the *Orthis subæquata* horizon. At Specht Ferry, ten miles up the river, there is a second shale bed separated from the green shales and their *subæquata* fauna by twenty-five feet of thin bedded, blue, fossiliferous limestone. In this locality the dolomitized Galena type of the formation begins above this upper shale bed, and so the beds which would ordinarily be referred to the Trenton, attain here a thickness of ninety-five feet in place of the sixty-five at the Eagle Point lime works. In Allamakee and Winneshiek counties the formation, as noted by McGee and others, becomes more argillaceous, especially toward the top, and the dolomitized portion which would be referred to the Galena, is limited to the comparatively few layers which overlie heavy beds of shale. Shale beds, while not necessarily the only factors, or even the most important ones, seem yet to have played an important role in controlling the depth to which the process of dolomitization was carried. If dolomitization in the present case was due to isolation of the Galena-Trenton basin, and concentration of the sea water which it contained, taking place after the beds composing the formation were all completed, it is easy to see how the descent of the process might effectually be stopped by beds of impervious shale. The conclusions of Winchell in 1895, and of Norton in 1897, appear now to be fully justified; and in considering the entire formation, as it is developed in Iowa, Wisconsin, and Illinois, geologists can do no better than to follow the example of Norton and call it the Galena-Trenton.

Geographical distribution.—The striking differences between the dolomitized and non-dolomitized parts of the formation make it convenient still to treat the two parts separately; and if the facts presented above are kept in mind, no confusion will arise from following previous custom and discussing one

portion under the name of Trenton and the other under that of Galena. With the understanding that the term has no formational significance, it may be said that the Trenton limestone is exposed along the bluffs of the Mississippi from Waupeton to Eagle Point. So far as this county is concerned, its outcrops are almost wholly limited to the bluffs fronting the river; it is never seen very far back in the interior of the county. With the exception of the Little Maquoketa, all the tributary streams joining the river between the point where the Mississippi first touches the border of the county and the point where the Trenton finally dips out of sight in the northern part of the city of Dubuque, are small, and the valleys or ravines which they follow have steep gradients. Accordingly in following each of these several ravines back from the mouth, it is found that the bottom rises above the level of the Trenton in a fraction of a mile; in most cases, indeed, within a very few rods. It is only along the Little Maquoketa that the Trenton is found at any considerable distance back from the Mississippi, and even here the exposures of this formation can not be traced very far up the valley, the last observed outcrops in this direction being scarcely more than three miles from the eastern border of the county. In addition to the exposed ledges of Trenton along the Mississippi bluffs, ledges of this formation are seen in a ravine in section 27, Peru township; there are some good exposures fifteen or twenty feet in thickness, at Thompson's mill, near Sageville, in the same township; and there are a few outcrops for a short distance along the stream, above the mill. Beds intermediate in character between Galena and Trenton occur at the foot of the bluff, by the side of the road leading from Sageville to Dubuque.

Lithological and faunal characteristics.—Counting all as Trenton above the Saint Peter and below the level of the dolomitized beds,—the Galena of authors,—the formation may

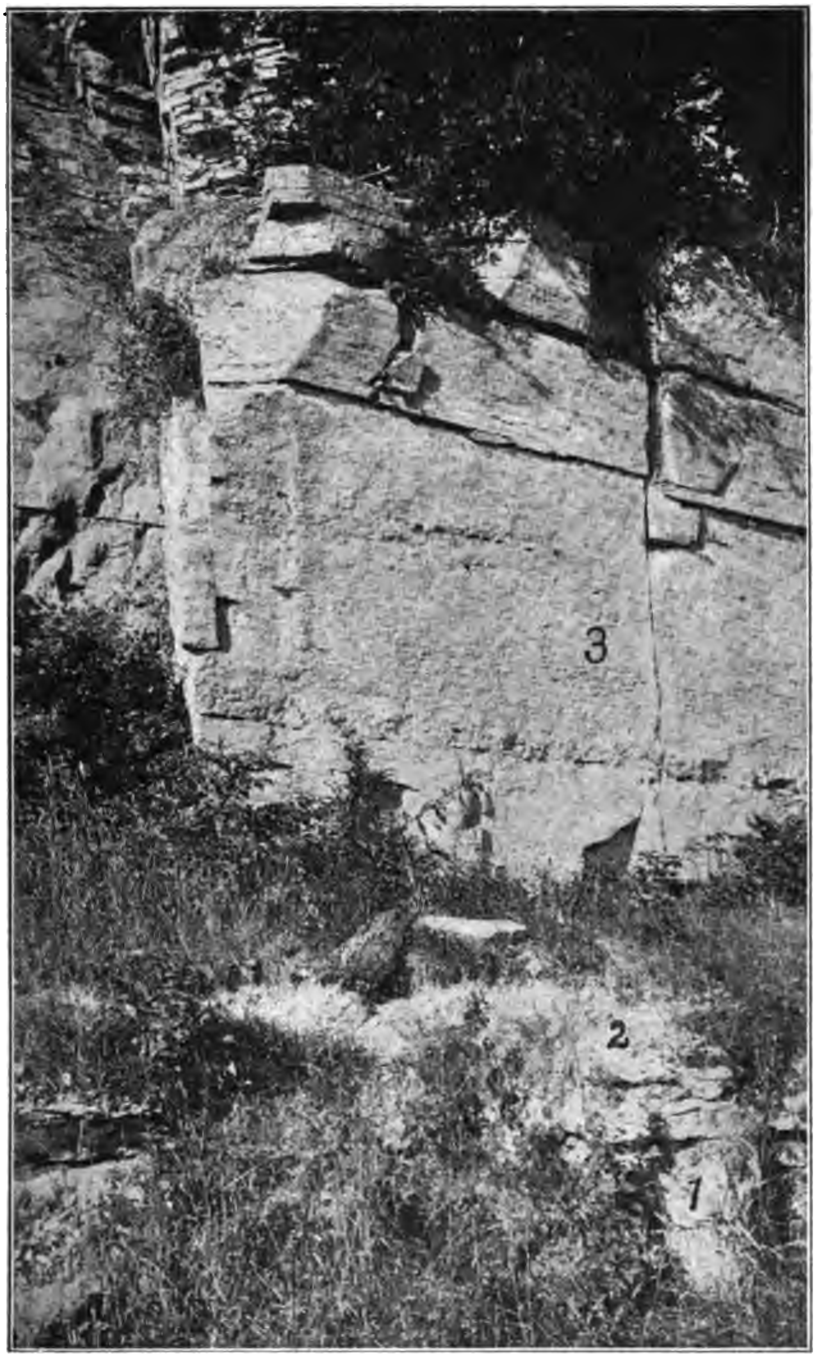

PLATE 5. View three-fourths of a mile below Specht Ferry, showing, in ascending order: 1. Saint Peter sandstone. 2. Basal shale. 3. Lower Buff beds. 4. Thin, brittle, blue beds.

be divided into a few recognizable divisions possessing distinctive lithological characteristics. The first member, resting on the Saint Peter sandstone, is a bed of bluish or greenish shale which weathers on exposure to ashen or yellow colors. In the report on Allamakee county, Volume IV of the present series of reports, this member is called the *basal shale*. It is very constant at this horizon so far as observations have been carried in Iowa; and reports indicate its presence very generally at the same geological level, in Wisconsin and Minnesota. The basal shale in Dubuque county will average about three feet in thickness, while farther north its thickness is increased to five or six feet. So far as noted it is quite barren of fossils; commercially it is of little importance.

Overlying the basal shale there are from eighteen to twenty feet of heavy-bedded, magnesian limestone, which, in the geology of Iowa and Wisconsin, have generally been known as "The Lower Buff Beds." The lower buff beds are best seen at the base of the bluffs, three-fourths of a mile below Specht Ferry. The individual layers vary from eight or ten inches to more than three feet. They are intersected by joints which cut almost vertically, and it is a smooth joint face, embracing the entire thickness of the beds, that is seen at the point referred to. The beds are earthy, impure, non-crystalline, and otherwise imperfect dolomite, very different from the coarse, granular, rough-surfaced, crystalline dolomite making up the typical portions of the overlying Galena. They are nevertheless hard and firm, and well suited for heavy masonry. The beds of this horizon are extensively quarried in the neighborhood of Minneapolis and Saint Paul, and, by reason of proximity to market, possess there no small degree of commercial value. In Dubuque county they have been quarried on a small scale in section 10 of Peru township; but in general they are neglected in Iowa, other formations furnishing desirable quarry products at localities less remote and less inaccessible from the points where building stone is in

demand. Owing to the small number of natural exposures, and the still smaller number of quarries which would afford opportunities for anything like thorough investigation, no satisfactory report can be made on the fauna of the lower buff beds. Organic remains are certainly very scarce, if they are not entirely absent in identifiable form. At least none which could be specifically or even generically recognized were seen at the few points where the beds are in position to be examined.

Next in order of superposition is an assemblage of thin layers of bluish, fine-grained, brittle, fossiliferous limestone, equivalent to part of the "Lower Blue Beds" of some authors. These thin beds reach a thickness of twenty feet. They afford an example of the typical blue Trenton, the "Blue Fossiliferous Limestone" of Owen's earlier report, the "Saint Peter's Shell Limestone," in part, of a report of later date. These beds weather to a drab, or sometimes to a light buff color. The layers are thin, and the bedding planes are very uneven and undulating, producing considerable variation in the thickness of the individual beds. In weathered exposures the shaly partings between the layers vary from a fraction of an inch to more than an inch in thickness, so that in such thin-bedded material there is the appearance of a large proportional amount of shale. The shale in these partings is, in places, quite bituminous; when lighted it burns freely with bright flame, emitting the odor and the dense smoke which usually attend the burning of bituminous matter. In unweathered parts of the formation the shale in the bedding planes is hard and compact, so much so that in a fresh vertical section the several beds seem to blend homogeneously one into the other through thicknesses of four or five feet. At the quarry, in section 10, Peru township, this feature is quite marked. The quarry is worked at the end of a high, sharp ridge with steep sides, so that there are weathered surfaces at both ends of the quarry face. In the middle of the face the layers of the lower blue beds are apparently blended together, the

partings showing but little difference in hardness and compactness from the purer calcareous portions of the deposits; while to the right and left, in the zones of weathering, as the natural surfaces of the two sides of the narrow ridge are approached, the thin bedding becomes oovious by the picking or weathering out of the less calcareous bands. These beds are well exposed, at short intervals, from Waupeton to Eagle Point, Dubuque. They make up the greater part of the section seen at the old Thompson mill at Sagetown. Everywhere they are fossiliferous, but the fossils are intimately blended with the matrix and are seen to best advantage when the layers are split horizontally. The most common species are *Rafinesquina alternata* Conrad, *Strophomena planumbona* Hall, a species which is sometimes of late identified with *S. rugosa* Raf., *Plectambonites sericea* Sowerby, *Orthis plicatella* Hall, *Orthis subæquata* Conrad, *Trochonema umbilicata* Hall, and fragments of a number of different species of trilobites.

Above the thin, brittle layers just described are five feet of heavier, coarser layers, not very fossiliferous, some of the ledges reaching a thickness of fifteen inches. These beds resist the weather admirably. They are followed by five feet of thinner, bluish beds, weathering brown, of coarser grain than those below, and not so fossiliferous. Adding these two members the total thickness of the division to which the term "Lower Blue Beds" has been applied in Wisconsin, is, in Dubuque county, thirty feet.

Above the lower blue beds are twelve feet of bluish or greenish shale, very soft and plastic, as a rule, but containing irregularly distributed through it, thin beds and thin lenticular sheets of limestone. The bed now under consideration corresponds to the "green shales" of Minnesota. The limestone flakes and thin sheets interbedded with the clay are very fossiliferous, consisting in most instances of crushed and broken brachiopod shells cemented together. The characteristic species of this horizon are *Orthis tricenaria* Con., and *Orthis subæquata* Con. but *Strophomena planumbona* Hall is a not

uncommon fossil, and dismembered portions of *Ceraurus pleurexanthemus* Green are found occasionally. Toward the Minnesota line this shale bed attains a much greater thickness than it has at any point in Dubuque county, reaching as much as thirty or forty feet in the neighborhood of Decorah and Waukon. The limestone beds associated with the shale are also more numerous and more persistent farther north, and are richer in organic remains. This is one of the most constant and most easily recognized members of the Trenton limestone in the Mississippi valley, but it evidently thins out, as do most of the other shale beds, as it approaches the region where the Galena limestone phase of the formation is best developed.

Lying upon the "green shales" is a bed of bluish, rather coarse-grained limestone, twenty-five feet in thickness, with disseminated, unrecognizable fossils, and made up of thin layers having a thickness ranging from three to six inches. Next in order are five feet of shales, or shaly limestones, or shales interbedded with thin seams of limestone. This bed varies greatly in the relative proportions of the argillaceous and calcareous matter which it contains. *Orthis testudinaria* Dalman, which is not seen below the top of the "green shales," is very common at this horizon, and here also is found *Orthis bellarugosa* Conrad. Associated with the species named are *Orthis plicatella*, *Rafinesquina alternata*, and *Plectambonites sericea*. The Trenton phase of the limestone never extends, in Dubuque county, above this last shale horizon, while at Eagle Point, Dubuque, the Trenton ends and the Galena begins at the top of the *Orthis subæquata* shales.

The foregoing general description of the Trenton limestone is based upon the following typical sections:

Three-fourths of a mile below Specht Ferry, along the railway track, there are some good exposures which show:

	FEET.
6. Steep slopes and vertical cliffs to summit of bluffs; the slopes covered with loose fragments, talus or scree; cemented in places, particularly on the lower slopes, with calcium carbonate deposited from springs; not measured..	

5. Thin-bedded, brittle limestone in flexuous layers; the limestone fine-grained and fossiliferous; the layers separated by shaly partings; a vertical exposure of.. 8
4. Heavy-bedded, magnesian, non-crystalline limestone, the "Lower Buff Beds" of authors.................. 20
3. Basal shale, weathering to yellowish and ashen tints.. 3
2. Saint Peter sandstone, much stained with iron oxide, in rather definite layers............................ 5
1. Unexposed to level of river........................... 25

A better section, giving more complete details of the Trenton limestone in this part of Iowa, is seen in the first ravine below Specht Ferry, only a few rods southeast of the station. This section shows:

FEET.

11. Thin-bedded, brown dolomite with shaly partings. (Galena).................. 4
10. Thin-bedded, imperfectly dolomitized limestone, with fossil brachiopod shells only slightly changed; the limestone brown, earthy, non-crystalline, but evidently of the Galena type............... 3
9. Thick, earthy, imperfectly dolomitized beds. (Galena.) 3
8. Thin limestone beds with much shale in the partings; in part a true shale. This member is almost entirely shaly a few rods above the station on the road leading to Dubuque. Fossils are numerous, the most common species being *Orthis testudinaria*, *O. bellarugosa*, *O. plicatella*, *Rafinesquina alternata*, and *Plectambonites sericea*.......................... 5
7. Limestone, bluish, rather coarse grained, with disseminated fossils; in beds varying from three to six inches in thickness........................... 25
6. Bluish or greenish shale containing occasional thin beds or discontinuous flakes of limestone; the characteristic fossils are *Orthis subæquata* and *O. tricenaria;* the "Green Shales" of the Minnesota geologists.......... 12
5. Thin-bedded, bluish, rather coarse grained limestone, weathering brownish in color.................... 5
4. Limestone in rather heavy layers which range up to fifteen inches in thickness; bluish on fresh fracture but weathering to buff on exposure.............. 5
3. Brittle, fine grained, blue limestone, very fossiliferous, breaking up on weathered surfaces into flexuous layers about two inches in thickness..... 20
2. Lower buff beds, exposed, about.... 8
1. Unexposed to level of water in river, about......... 45

Numbers 2 to 8 in the above section belong to the non-dolomitized portion of the formation, which has usually been recognized as the Trenton. Numbers 9 to 11 represent the dolomitized phase which has quite generally been referred to a distinct formation and called the Galena limestone. A few rods southwest of the Specht Ferry station, on the Dubuque road, a small gorge cut in the bluff on the east side of the road reveals essentially the same section as that just recorded. From the top of the Saint Peter sandstone to a plane above the middle of number 3, a distance vertically of about fifty feet, the beds are not exposed, but from number 3 up, the succession is just the same, except that number 8 is practically a pure shale which weathers into a plastic, unctuous, blue or yellow clay.

A quarry in section 10 of Peru township, two miles below Specht Ferry, gives an artificial section which shows some details not seen in the natural exposures. At this point we have:

		FEET.
5.	Blue, thin-bedded limestone, at the top of the section.	2
4.	Shale, the equivalent of the "Green shales"	8
3.	Heavy ledges of fairly good building stone, bluish, but weathering into buff on exposed surfaces, equivalent to numbers 4 and 5 of the Specht Ferry section... .	10
2.	Thin-bedded, brittle, blue, fossiliferous limestone...	16
1.	Heavy lower buff beds, good quarry stone............	10

The quarry here described, as noted on a preceding page, is worked across the end of a narrow, sharp ridge. In the middle of the quarry face, where it has not been exposed to weathering, number 2 appears to be made up of heavy beds four or five feet in thickness. The ordinary bedding planes which, on weathered surfaces, divide this member into thin, flexuous layers only a few inches thick, are brought out conspicuously only by exposure to the weather. Before such exposure the alternating bands of calcareous and more argillaceous material appear equally solid and are blended together so as to present the superficial appearance of homogeneous, massive ledges. Toward the sides of the quarry face, near

the exposed surfaces of the ridge, number 2 assumes its usual characteristics of thin-bedded limestone with shaly partings. In the loose material at the foot of the vertical cliff which now forms the breast of the quarry there were slabs of fossiliferous limestone containing *Orthis subæquata* and the associated fauna of the green shales horizon.

The exposures above the mill near Sagetown belong to numbers 2 and 3 of the Specht Ferry section. At the lime works near Eagle Point, Dubuque, there are beds carrying the green shales fauna, the equivalent of number 6, exposed immediately beneath the Galena limestone.

GALENA LIMESTONE.

The phase of the Galena-Trenton, which has come to be known as the Galena limestone, attains a greater development and has a much wider distribution in Dubuque county than the Trenton. In its typical exposures the Galena is a rather dark, buff-colored, granular, highly crystalline dolomite; but the formation varies considerably at different levels throughout its thickness, and it varies also, to some extent, in different localities. At no one point was it possible to get an entire section of the Galena limestone, but all parts of the formation—from its base in contact with the Trenton to its uppermost thin, earthy, almost shaly layers in contact with the overlying Maquoketa—may be studied satisfactorily within the city of Dubuque. The following specific descriptions and detailed sections, better than any general discussion, will convey some idea of the characteristics of this formation as it is developed in the area under consideration. One of the best sections is that at the Eagle Point Lime Works. Beginning at the top of the bluff it shows:

		FEET.
15.	Loess-covered slope above the outcropping ledges of Galena limestone, culminating in a prehistoric mound at the summit of the bluff..................	15
14.	Ledges of well dolomitized Galena, varying from two to three feet in thickness..................	10

13.	Two or three rather heavy ledges containing large numbers of the problematic fossil, *Receptaculites oweni* Hall. Receptaculites is found sparingly in other members of the section. At this horizon, which will be called the Receptaculites zone, it is exceedingly abundant	10
12.	Heavy-bedded, typical Galena, hard, crystalline and relatively free from chert; in ledges three to six feet in thickness	70
11.	Bed containing pockets of calcite; the calcite in some cases forming large crystals	3
10.	Bed containing large quantities of chert	4
9.	Ledges showing the characteristics of the typical Galena, hard, compact, crystalline, completely dolomitized, with small amount of chert	18
8.	Thick, massive beds with large amourt of chert	12
7.	Thick beds of crystalline dolomite, the ordinary type	6
6.	Ledge varying in texture, containing small pockets of calcite and some chert; a single specimen of Receptaculites found in this ledge	4
5.	Heavy ledge nearly on a level with the top of lime kiln	3
4.	Dolomite varying in aspect according to degree of weathering; at Eagle Point showing bedding planes 10 to 18 inches apart	15
3.	Massive, crystalline dolomite; bedding planes almost completely obliterated	20
2.	Incompletely dolomitized beds with shaly partings at intervals of six, eight, or ten inches	10
1.	Basal ledge of Galena, beginning on top of Trenton limestone and shale bearing *Orthis subæquata* and associated fauna; this lower bed is earthy, incompletely dolomitized, and weathers below into a dark brown or reddish ferruginous clay	2

A few feet of shales and non-dolomitized limestone, carrying the green shales fauna, are exposed at the foot of the vertical cliff a few rods south of the lime kiln. The base of the Galena at this point is about thirty feet above the medium summer stage of water in the Mississippi river at the Eagle Point ferry landing. The exposure of the Trenton shale and limestone referred to coincides in position with one of the numerous small anticlinal folds seen in this county. The quarry worked to supply material for the lime kiln is located north of the axis; and in the quarry the dip, which is a little east of north, amounts to about one foot in twenty. All the beds of

the Galena are intersected with joints which trend and hade at different angles. The joint faces are usually, in some instances heavily, coated with stalagmite.

The chert-bearing beds, which begin in number 6 and range up into the lower part of number 12, constitute a well marked horizon, the significance and importance of which will be brought out in the discussion of the economic products of the Galena limestone. This chert horizon is well illustrated at the foot of the bluffs all the way from Seventeenth street southward to the mouth of Catfish creek. It is exposed through a thickness of fifteen or twenty feet, on the south side of Julien avenue, a short distance above Bluff street. At the Fenelon Place elevator on Fourth street the nodules and concretions of chert characteristic of this zone are quite conspicuous, and range up through a thickness of thirty feet. The same zone is well exposed in the cliffs along the track of the Illinois Central railway, from a mile to a mile and a half south of the station. From the Eagle Point anticline the beds dip somewhat uniformly toward the south or southwest, and so below the mouth of Catfish creek the chert beds soon disappear below the level of the railway embankment.

In the cliffs along the south side of Julien avenue the chert beds are followed by heavy ledges corresponding to those forming the upper sixty feet of number 12 of the Eagle Point section. These ledges are overlain by Receptaculites beds ten feet in thickness, as is well shown by the recently quarried massive layers a few yards south of the point where Hill street joins the avenue. Above the Receptaculites beds, which are the equivalent of number 13 at Eagle Point, there may be made out, on the east side of Hill street, thirty feet of only moderately heavy, thoroughly dolomitized beds, the basal part of which, only, is represented by number 14 of the detailed section above described. Numbers 12, 13 and 14 constitute the characteristic part of the Galena. The beds in general are thick, heavy, hard, completely dolomitized, rather crystalline and relatively free from chert. It is these

beds which form the conspicuous walls and precipices on both sides of Fifth street, beginning a short distance above Bluff and continuing well up toward the summit of the hill. To them, it is, we owe the picturesque buttressed walls so impressively prominent about the middle height of the bluffs at so

Fig. 46. Towers of Galena limestone above level of chert beds; seen in valley of Catfish creek west of Rockdale.

many points within the city of Dubuque. They form the majestic towers and castles (Fig. 46) seen from the trains of the Illinois Central railway a short distance west of Rockdale; while the vertical walls which guard the narrow valley of Catfish creek in the vicinity of Dubuque's grave, are examples of Nature's masonry built of these same ledges. Beds of this horizon showing the same characteristics are seen in the picturesque castles and mural escarpments in the valley of the Little Maquoketa, from one to two or three miles southwest of Durango. It will be unnecessary to mention all of the numerous localities at which this characteristic phase of the Galena is exposed. The point most distant from Dubuque where it was observed, with features practically unchanged, was in the valley of the small creek which traverses the W. ½ of the Ne. ¼ of Sec. 22, Jefferson Tp.

Here the stream flows at the foot of vertical walls of typical Galena limestone, thirty to forty feet in height.

As noted above, thirty feet is assigned to the somewhat arbitrary division of the Galena limestone, which lies next above the Receptaculites zone. About the middle of this

Fig. 47. Galena limestone at level of "cap rock." C, Cap rock; D, Thinner layer below cap rock.

division occurs the "cap rock" of the miners, a heavy firm layer about two and a half feet in thickness. Below the heavy "cap rock" there is usually another firm layer eight to nine inches thick, below which there are softer beds which disintegrate readily and produce caverns of varying dimensions, particularly where the strata have been cut by joints. These features are well shown in Figure 47. Toward the top of this member the beds are somewhat thinner than near the base, and throughout its whole thickness the bedding planes are nearer together than in numbers 12 and 13 of the Eagle Point section. Few of the layers exceed two and a half feet in thickness, and many are much less. In this horizon are located most of the quarries, which in this vicinity, furnish the material for heavy, substantial masonry.

Above the division just described the Galena becomes thin-bedded, earthy, soft and non-crystalline. Dolomitization is imperfect. The layers range from three to ten or twelve inches in thickness; the thicker beds being near the base, and the layers becoming progressively thinner toward the top. Shaly partings between the strata are more common in this division than elsewhere in the formation under discussion; the thickness of the bands of shale, in the upper part, become equal indeed to the thickness of the alternating layers of limestone. As a matter of fact the limestone, in the very upper part, is not infrequently reduced to mere rows of disconnected nodules embedded in clay. This is the uppermost member of the Galena limestone. It is overlain directly by the Maquoketa shales. The total thickness is somewhat variable, but it will average about thirty feet. The division is not definitely separated by any well marked line from the member below. It has beds of fairly good quarry stone toward the base; the calcareous bands and nodules of the upper part are practically worthless. The member here discussed is exposed in an abandoned quarry located in the angle north of Fifth and east of Hill street. The very uppermost part of it is seen, in contact with the base of the Maquoketa shales, at the brow of the hill on West Eighth street, a few yards east of Pine. It has been quarried quite extensively on the north side of West Fourteenth street, near Cox, and at a number of other places a block or two north of Fourteenth street in West Dubuque. At the quarry near Cox street three or four feet of Maquoketa shales occur above the Galena at the top of the excavation. A number of quarries are worked in the lower part of the thin-bedded Galena, and down into the upper part of the underlying member, along Dodge and South Dodge streets.

At many other points within the city limits are the upper beds of the Galena exposed, but the quarries and natural sections already noted are sufficient to illustrate the characteristics of this formation. So far as observed these characteristics are very constant and are easily recognized. The total thickness of the Galena limestone at Dubuque includes numbers 1 to 13 of the Eagle Point section, which, to the top of the Receptaculites zone, gives an aggregate of 177 feet. To this must be added the Hill street section, from the top of the Receptaculites zone to the top of the abandoned quarry between Hill and Fifth streets, or up to the contact with the Maquoketa shales on West Eighth street. This gives for the part above the Receptaculites beds:

		FEET.
15.	Thin-bedded Galena limestone, earthy, non-crystalline; the layers ranging from ten or twelve inches near the base to less than three inches in thickness near the top; upper part of this member very shaly; carries as fossils *Lingula iowensis*, *Liospira lenticularis* and *Conularia trentonensis*....................	30
14.	Well dolomitized Galena in layers ranging from one to two and a half feet in thickness; with softer beds near the middle, which frequently disintegrate so as to form caverns; basal part only, of this member, represented above the Receptaculites beds at Eagle Point..	30

Adding the sixty feet of numbers 14 and 15 to the 177 feet represented by numbers 1 to 13 at Eagle Point, the total thickness of the Galena limestone at Dubuque is found to be 237 feet.

Outside the city limits there are numerous exposures of the upper portion of the Galena, those corresponding to number 15 of the Dubuque city section being readily recognized by the earthy character of the rock, by the thin bedding, and by the relatively large amount of shale in the partings between the strata. The Graf quarry, a short distance west of Twin Springs, in the Sw. ¼ of the Se. qr. of Sec. 16, Center Tp., is worked partly in the upper member of the Galena, number 15, and partly in the better dolomitized beds, number 14, which

lie immediately below it. Along the railway track, between Twin Springs and Graf, there are a number of rock cuts showing the upper, earthy beds; and in one of these cuts, the first southwest of the Graf quarry, the Galena is overlain by from four to six feet of Maquoketa shales. (Fig. 48.) As usual the

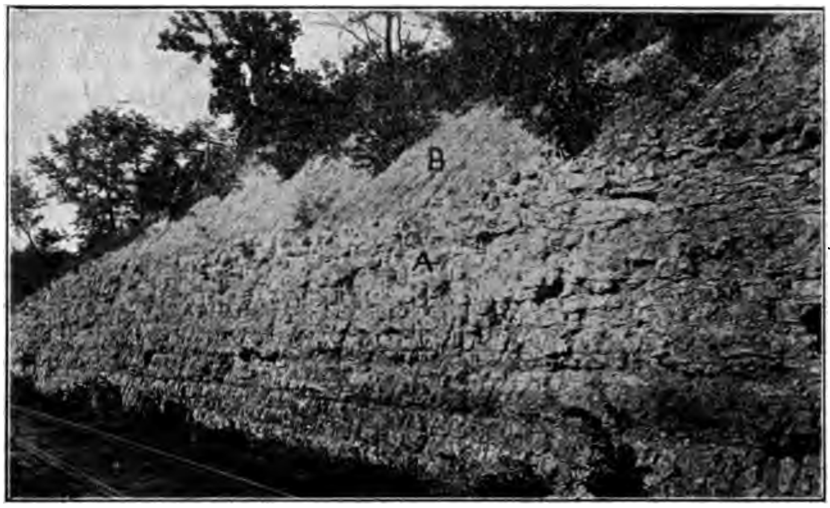

Fig. 48. A, Upper thin-bedded portion of Galena limestone; B, overlying Maquoketa shales.

Galena is nodular and shaly toward the top, but the transition to the Maquoketa is, nevertheless, very abrupt. The same abrupt change in the character of the sediments is strikingly shown on West Eighth street in the city of Dubuque, and at all the numerous points throughout the county where the contact of the two formations was observed. The Se. ¼ of Sec. 20, Center Tp., affords many good exposures of the upper portion of the Galena and of its contact with the overlying Maquoketa. There is here a strong dip to the southwestward, so much so that a short distance beyond Graf, less than a mile from the locality above noted, the Galena has disappeared below the bed of the small stream, and the level of the railway grade is forty or fifty feet above the base of the Maquoketa. In section 31 in the northern part of Jefferson, in T. 91 N., occur the last exposures of the Galena limestone in this direction,

in the county. Barometric measurements give the formation here a thickness of about 200 feet. The beds as a whole are less massive, and less compact and crystalline, than those making up the middle portion of the Galena at Dubuque. The typical characteristics of the formation seem gradually to fade out toward the northwest, so that in northern Clayton, southern Allamakee, and central Winneshiek, dolomitization has affected only a small part of the layers which constitute the typical Galena in the lead mining districts of Iowa, Wisconsin and Illinois.

MAQUOKETA SHALES.

In Dubuque county the formation which immediately overlies the Galena limestone, as this limestone is described in the foregoing section, is argillaceous throughout its entire thickness. There are a few bands containing more or less of calcium carbonate, but none of the beds could properly be characterized as true limestone or dolomite. The formation is found, however, to be exceedingly variable, lithologically and paleontologically, when traced through the counties north and northwest of Dubuque. The variations referred to are local, very great diversity occurring not unusually at localities separated by only a few miles. In a general way, though it is not universally true, the formation becomes more calcareous toward the northwest; and, as at Peterson's spring, in Fayette county, it acquires locally bands of true limestone embedded in bluish or greenish clay.

Since the presence of a body of shale between the Galena and Niagara limestones was announced by Hall in 1858, the formation has received a large share of attention at the hands of geologists. Scarcely any formation in this geological province has been written about more persistently; scarcely any has been more misunderstood; with respect to no other has there been greater diversity of judgment and interpretation; in no case is it more obvious that some of the latest attempts to harmonize discrepant opinions have involved the whole

subject in more inextricable confusion. The terms Hudson River shales, Cincinnati shales, Utica shales, Maquoketa shales, together with numerous less generally known local names, have all been severally applied to the formation in question, as it is developed in Iowa, Minnesota, Wisconsin, and Illinois. For the literature of the subject the reader is referred to the writings of Hall,* Meek and Worthen,† White,‡ Chamberlain,§ Strong,‖ James,** Winchell,†† McGee,‡‡ and Sardeson.§§

Without attempting to harmonize all the discrepant opinions held and expressed respecting the name of the formation, or the stratigraphic limits which should be assigned to it, it is sufficient to say that, so far as Dubuque county is concerned, no confusion need arise from the use of the term Maquoketa shales, as applied by White; nor will anything be lost either in the way of clearness or scientific accuracy if, stratigraphically, the formation is limited by the top of the great body of dolomite belonging to the Trenton series, and the base of another great body of dolomite which belongs to the Niagara series. These two limits are here perfectly definite and precise; their use is in accord with the most rigid of scientific requirements; and the great body of shale—200 feet in thickness—which lies between them, is sharply set off by lithological and paleontological characters from both dolomitic formations. Among the authors who have recently written on the subject, one proposes to draw the line between

*Report on the Geol. Surv. of Iowa, by James Hall, 1858; and Reports on the Geol. Surv. of Wisconsin, 1861 and 1862.

†Proceedings Phil. Acad. of Sci, 1865; and also Geol. Surv. of Illinois, Vols. I, II, III, and VII.

‡Report on the Geol. Surv. of Iowa, by Charles A. White, 1870.

§Geology of Wisconsin, survey 1873-1877, 1877.

‖Geology of Wisconsin, survey 1873-1877, 1877.

**American Geologist, Vol. V, 1890; Pro. Am. Ass'n for the Adv. of Sci., Vol. XXXVIII, July, 1890.

††See Reports on the Geol. Surv. of Minnesota; particularly Vol. III, Part II, of the Final Report, introduction, page CI.

‡‡Pleistocene Hist. of Northeastern Iowa; U. S. Geol. Surv., Vol. XI, 1891.

§§*American Geologist*, Vol. XVIII, p. 356; and same Journal, Vol. XIX, 1896, 1897.

the Galena and the Maquoketa about the top of the Receptaculites zone, and so transfer some fifty or sixty feet of dolomite to the Maquoketa formation; but such a proposition can scarcely be taken seriously.

From the Galena the Maquoketa formation differs as much in respect to the physiographic conditions under which it was deposited, as in the matter of lithological and paleontological characters. During at least the later part of the age represented by the Galena limestone, the area now occupied by Dubuque county was a part of an isolated, or partially isolated, sea basin in which the waters were bitter, and concentrated to such an extent as to produce dolomitization of all calcareous sediments. With the beginning of the age now called Maquoketa, this land-locked sea with arid shores gave place to a body of water communicating freely with the open ocean; and mechancial sediments, indicative of generous rainfall, were laid down in sea water of normal density. Taking prompt advantage of the new physiographic conditions, types of life,—some new to the region, and some of species which had been present when the normal waters of the Trenton sea occupied the area,—established colonies which soon spread a dense population over the new sea bottom. Not all the old forms came back, and some that did, did not return until the Maquoketa age was fully half complete. *Plectambonites sericea*, for example, is common in the strata immediately above the "Lower Buff Beds" of the Galena-Trenton. It disappeared from this particular part of the province before the close of the Galena; it is absent from the lower half of the Maquoketa; but it reappears in force above the middle of the formation, and is in places one of the most abundant and characteristic fossils in beds which lie within a few feet of the base of the Niagara.

While the upper part of the Galena contains a large proportional amount of argillaceous material, calcareous beds predominate; and the effects of the conditions which brought about dolomitization are strongly expressed up to the dividing

line which marks the abrupt beginning of the Maquoketa. A number of points at which the change from Galena to Maquoketa may be seen, have been already mentioned; and at all these points the transition is indicative of a very sharp break. Even after the Maquoketa began, the conditions were for

Fig. 49. Railway cut in Maquoketa shales west of Graf.

some time unstable, and fluctuations are recorded in the varying character of the deposits. All the characteristics of the lower part of the shale may be studied within the limits of the city of Dubuque. The exposures on the slope of the bluff on West Eighth street, and those at the top of the quarries in many parts of the city, as on Fourteenth street, show the variable character of the first five or six feet of the shale, and the sharp manner in which it is set off from the underlying Galena. The mineral shafts on the high ground, back from the face of the bluffs, not infrequently penetrate fifty or sixty feet of shale before reaching the Galena. It is the region, however, in the neighborhood of Lattners and Graf, in Center township, which has become classic in connection with the study of the formation now under consideration. Here on the banks of the Little Maquoketa are the typical exposures to

which Hall and White, and James, and many others less prominent, have resorted for the information made use of in contributing to the literature of the subject. From the little stream that flows at the foot of the bluffs in which the exposures occur, the formation gets the name applied to it by White. To this locality the student must to-day resort, if he would study, with greatest success and least labor, the characteristic aspects of the deposits. About one-half mile west of Graf station, the Great Western railway has made a cut through the Maquoketa shales (Fig. 49) at the level of the principal section studied by Hall and White. It was this cut, together with a number of exposures in adjacent washes and ravines, which was examined by James. In this cut the writers of the present report noted the following section:

		FEET.	INCHES.
17.	Drab to black, argillaceous, unfossiliferous shale	2	
16.	Sixth Orthoceras bed; brownish, hard, granular, non-fissile shale, with numerous specimens of the minute, brad-like shells of *Coleolus iowensis*, some small gastropods, a few specimens of *Orthoceras sociale*, together with cephalic shields and pygidia of *Calymene mamillatus*	1	2
15.	Shale, drab, very fissile, somewhat sandy, no fossils	1	4
14.	Fifth Orthoceras bed; light brown, earthy, non-laminated, rather hard layer which some writers have described as limestone; not very calcareous; crowded with shells of *Orthoceras sociale*, which are generally crushed and otherwise imperfect; some of the partially decomposed shells still retaining the original nacreous luster	1	
13.	Fissile, slaty shale, dark gray in color, containing many blade-like, or sheath-like impressions of a fossil which Ulrich has described under the name of *Spatiopora iowensis*	0	6
12.	Fourth Orthoceras bed, lithologically the same as number 14, Orthoceras very numerous and crowded, more perfect than in 14.	0	6–8
11.	Shale varying in thickness, dark gray in color.	0	1–3
10.	Third Orthoceras bed, resembling 12 and 14	0	10

9. Thin bed of dark, fissile shale; irregular as to thickness, in some places reduced to a mere parting	0	1–3
8. Second Orthoceras bed, lithologically like 10, 12 and 14	1	
7. Shale, dark brown, imperfectly laminated, rather coarse-grained and earthy, crowded with *Diplograptus peosta*	0	5
6. First Orthoceras bed, like number 8	0	4–8
5. Shale, brown, fissile, fossiliferous	0	7
4. Shale, earthy, granular, non-laminated; with many comminuted fossils and perfect shells of *Coleolus iowensis*, *Murchisonia gracilis*, *Liospira micula*, and other species	2	
3. Shale, dark brown, non-fissile, with a species of Lingula three-eighths of an inch long and one-fourth of an inch wide	2	
2. Shale, dark, bluish-black, fissile or slaty, containing large numbers of *Leptobolus occidentalis*, and two species of Lingula	2	2
1. Shale, brown or black, non-fissile, fossils rare, occasional specimens of a Lingula half an inch long and three-eighths of an inch wide	6	

Among the features of special interest in this part of the Maquoketa section are the Orthoceras beds, numbers 6, 8, 10, 12, and 14; the Spatiopora bed, number 13, and the Diplograptus bed, number 7. The layers in which Orthoceras occur are composed of hard, non-laminated rock resembling some phases of limestone or dolomite. They have indeed been described as limestones or dolomites by some of the writers who have discussed this section, but they are simply indurated beds of clay with which is mixed a small amount of calcareous material. The Orthocerata are crowded together and telescoped one into the other in a way that resembles the promiscuous arrangement of shells of other species of mollusks, which to-day, by the action of waves and tides, are heaped in winrows along the sea beach. The nature of the Orthoceras beds and the accompanying deposits, together with the width of the area over which they are distributed, precludes the hypothesis of a littoral or beach deposit; but indicates rather that these shells were tossed about and were

finally spread, more or less evenly, over a considerable area of shallow-sea bottom. Number 13 is an exceedingly definite and well marked bed, consisting of dark, laminated shale divided into prismatic blocks by clean cut, intersecting joints. The feature, however, which is shared by no other member of the section, is the tapering, blade-like fossils that Ulrich has identified as Bryozoa and described under the name of *Spatiopora iowensis*. Ulrich* believes that these Bryozoa grew as encrusting films on the outer surface of the shells of *Orthoceras sociale;* and that by some process of maceration and compression the Orthoceras shell has completely disappeared, while the zoaria of the several encrusting colonies of Bryozoa have been preserved. The skeletal part of the organism which made these impressions was elongate-conical and sac-like as to structure, and the sac possessed thin, delicate, reticular walls. The thin-walled sac is now compressed, with the inner surface of one side in close apposition with the inner surface of the other. It is the inside of the sac that is generally presented to the observer, for in separating the shaly laminæ between which the fossils are embedded, one-half of what is left of the original structure usually adheres to each lamina. Occasionally the separation takes place in such wise as to leave parts of both halves of the compressed sac on one of the separated laminæ, and then it is seen that the outer and inner surfaces are markedly different in certain details of structure and color. Graptolite markings and impressions are common in nearly all the shaly portions of this part of the deposit; but bed number 7 is distinguished from all the rest by the great number of delicate stipes which it contains, and the remarkable perfection of their preservation. All, or practically all, of those occurring in this particular zone belong to the species *Diplograptus peosta* Hall. Indistinct impressions of a species

*The Geology of Minnesota, Vol. III, Part I, of the Final Report; p. 321.

which is probably *Diplograptus pristis* Hisinger, occur, sometimes in great numbers, at different levels, in the shaly portions of the section.

Owing to the rapidity with which the Maquoketa shales disintegrate as a result of weathering, exposures of the for-

Fig. 50. View near Graf showing the effect of the Maquoketa shales on the topography. The rounded swells and long, cultivated slopes are underlain by shales; the steep, wooded hill in the distance is composed of the overlying Niagara limestone.

mation soon become concealed with products of decay, and "sodding over" follows in a comparatively short time. The formation, accordingly, does not form permanent cliffs; continuous vertical sections of any considerable thickness are not to be found except in the bottom of some creek which is still vigorously scouring its channel; and exposures of any kind are comparatively few. The formation expresses itself in the landscape in gracefully rounded swells and long, gentle slopes (Figure 50). The Little Maquoketa, in the central part of Center township, washes the base of steep bluffs of Galena limestone; away up on the rim of the valley, 200 feet higher, the Niagara limestone forms a nearly vertical escarpment; between the two cliff-forming limestones are the long, gently rolling and cultivated slopes of the Maquoketa shales, as is

partly illustrated in the figure above referred to. On these long hillsides the rain, here and there, cuts gullies deep enough to expose the unweathered shale, and thus afford the student an opportunity to learn, though in a fragmentary way, the characteristics of the deposit at different altitudes above its base. A number of these gullies are found southeast of the stream in section 29, and on the opposite side of the stream in section 20 of Center township. One of the best sections of this formation, so far as observed, is that which is found in the bed of an intermittent creek in the Sw. ¼ of the Se. qr. of Sec. 20. The ravine cut by the creek is followed by the road leading westward from Hill's mill. Here the following, which may be called Hill's mill section, is exposed:

		FEET.	INCHES.
30.	Blue and green plastic clay shales concealed in slope, except at contact with number 29; thickness not measured		
29.	Shale, yellowish; weathering to plastic clay	1	
28.	Indurated, stony beds, yellow	0	3
27.	Shale, laminated, fissile, yellow	2	
26.	Dark drab, non-fissile shale containing a few specimens of a small Orthoceras, a different species from *O. sociale* Hall	0	3
25.	Fissile, slaty, bluish shale; weathering yellow	0	6
24.	Yellow, stony, calcareous, non-laminated bed, with some specimens of *Murchisonia gracilis* and numerous small lingulæ	3	
23.	Drab, slaty shale; equivalent to numbers 16 and 17, Graf section	2	
22.	Shale	1	
21.	Fifth Orthoceras bed; forty feet above base of the formation	1	
20.	Shale; equals number 13 at Graf	0	6
19.	Fourth Orthoceras bed; equals number 12	0	6
18.	Thin seam of shale; equal to number 11	0	2
17.	Third Orthoceras bed; equal to number 10	0	10
16.	Shale; equal to 9	0	2
15.	Second Orthoceras bed; equal to number 8	0	10
14.	Drab, fissile shale	0	3
13.	Non-laminated shale, with shells of *Murchisonia gracilis*	0	3
12.	First Orthoceras bed; equals number 6 of Graf section	0	6
11.	Brown, fissile shale; equals number 5 of Graf section	1	

10.	Non-laminated, fossiliferous bed; equal to number 4	2	
9.	Brown, fissile shale; equal to number 3	2	
8.	Earthy, fossiliferous shale, not represented at Graf	0	2
7.	Blue, slaty shale, with the fossils of number 2 at Graf	1	2
6.	Hard, yellowish, barren shale	0	3
5.	Laminated shale with the large lingulæ of number 1 at Graf	13	
4.	Bluish or drab, laminated shale, with traces of graptolites and numerous specimens of Leptobolus and Lingula in the lower part; upper part barren	8	
3.	Bluish, unfossiliferous, laminated shale	8	
2.	Shale, variable in color and texture, but in general non-laminated and coarse, very fossiliferous, carries a small species of Orthoceras, *Liospira micula*, *Pleurotomaria depauperata*, *Hyolithes parviusculus*, *Cleidophorus neglectus*, and *Ctenodonta fecunda;* the last named species very common	2	
1.	Upper beds of the Galena limestone showing the usual thin layers, layers becoming progressively thicker from above downwards; exposed in vertical walls in bank of stream	15	

In the bottom of the creek in which the above section was observed, and in some of the side ravines, the contact of the Maquoketa and Galena is well shown. From observations in the bed of the stream, made at what seemed to be the line of contact between the two formations, James* believed there were indications of pre-Maquoketa erosion of the Galena, and reached the conclusion that the shales are separated from the limestones by an unconformity. It is just possible that the author referred to, with observations limited to the narrow dimensions of the creek bed, was misled by overwash of clay upon recently eroded Galena. At all events, in making the present survey, evidences of unconformity, indicated by an intermediate erosion interval, were carefully sought, without success, at all the points where the contact plane is exposed. Though the change from limestone to shale is quite abrupt, the sedimentation planes on the two sides of the contact line,

*American Geologist, Vol. V, p. 344, 1890.

in Dubuque county, are everywhere parallel; the continuity was evidently unbroken.

In this connection, however, it may be well to say that, notwithstanding the absence in this county of evidence of unconformity due to overlap upon an eroded surface, there are reasons for believing that in some localities the Maquoketa may rest unconformably on the Galena-Trenton. It has been said that probably the Galena limestone owes its dolomitic character to the fact that, toward the close of the interval represented by the formation named, the area now occupied by the lead-bearing limestone was an isolated, or partly isolated, basin in which the sea waters were concentrated by evaporation. The city of Dubuque is located in what was the central part of this land-locked basin. In order that the concentration necessary to produce dolomitization of the limestones might be possible, it is a fair assumption that the interval was one of arid climate, one in which loss by evaporation exceeded the volume of drainage waters received by the basin from the adjacent lands. For a large share of the Galena interval, on account of ineffective erosion, but little land waste found its way to the Dubuque region. The thin, irregular beds of limestone with shaly partings, in the upper part of the Galena, may be interpreted in two ways. The phenomena may mean that, before the Galena came to a close, rainfall increased, erosion became more energetic, and a greater proportionate amount of mechanical sediments was the logical result. All the facts, however, taken together, seem to point, not to any increased rate of erosion beyond what had taken place in the preceding portions of the arid Galena interval, but to constantly waning energy on the part of the life forms which contributed the limestone-making materials, owing perhaps to the fact that the increasing salinity of the waters rendered the conditions more and more unfavorable to the existence of life. It is upon beds laid down under the conditions described that the Maquoketa shales were deposited. As has been said, the change is abrupt.

The very first of the shales bear evidence of copious rainfall on land and normal conditions of salinity in the water. In the lower two or three feet of the shales there are many rolled pebbles of limestone, which must have been carried in from the sides of the basin; and while there is no evidence that the Galena limestone of our area suffered erosion before the deposition of shales began, the rolled pebbles and other materials at the base of the Maquoketa point to the possibility of erosion of contemporaneous beds not far away. Such an eroded surface, overlain by shale, may yet be found toward the northwest.

Number 2 of the Hill's mill section, the lowest member of the Maquoketa formation, may very properly be called the Ctenodonta bed. The characteristic fossils which it contains, on account of their great numbers and perfect preservation, are sure to arrest the attention of any observer studying the details of this part of the geological column, no matter in what part of the county exposures of this horizon may be found. Above the Ctenodonta zone, up to the first Orthoceras bed, the formation consists almost exclusively of blue or drab, indurated, slaty shales which break up into thin, hard flakes, but do not disintegrate into a plastic clay. There are occasional yellowish or brownish, non-laminated layers interbedded with the fissile shale, but the aggregate thickness of these is inconsiderable. The same conditions, practically, are continued through the Orthoceras beds and up to number 28 of the Hill's mill section. Above number 28 the formation changes suddenly, so that the line between 28 and 29 divides the formation into two very distinct portions which may be designated, respectively, the Lower and the Upper Maquoketa. The Lower Maquoketa, from fifty to sixty feet in thickness, is made up of the lean, non-plastic beds already described; the Upper Maquoketa is at first composed largely of green and blue, plastic, non-fossiliferous shales, but in the last twenty-five feet below the Niagara the shales give place

to transition beds which are represented by thin layers of shaly, impure dolomite.

The Lower Maquoketa varies somewhat in thickness. The thickness is slightly less than fifty feet at Hill's mill; but in the Ne. ¼ of Sec. 20, Jefferson Tp., it exceeds seventy feet. The thickness of the Upper Maquoketa is approximately 150 feet. The thickness of the entire formation is much greater than has been heretofore reported; it varies from more than 200 feet in Mosalem township, to about 175 feet in the northwestern part of Jefferson. The relations of the several parts of the formation are shown in the following diagram:

Upper Maquoketa. 150 feet.	Transition beds, thin layers of impure, earthy dolomite.
	Plastic clay shales, with some indurated, fossiliferous bands near the top.
Lower Maquoketa. 50 feet.	Lean, fissile shales, with some earthy, non-laminated beds carrying Orthoceras and other fossils.

The lithological and faunal differences between the Lower and Upper Maquoketa, deserve more emphasis than they have yet received. The Upper Maquoketa, as has been said, is made up chiefly of plastic, unfossiliferous clays. These clays are well adapted to the potter's art. They weather more rapidly than the beds of the lower division, for which reason natural sections are exceedingly rare. They are seen at intervals in ravines leading down to the Little Maquoketa valley, north of Epworth. The Great Western railway has cut through beds of this horizon at a number of points both east and west of Kidder station. One of the best of the observed exposures of the Upper Maquoketa is found in a ravine in the Nw. ¼ of Sec. 27 and the Sw. ¼ of Sec. 22, Mosalem Tp. Between Julien and Peosta the Illinois Central railroad cuts through these upper beds at a number of points, but, owing to weathering and growth of sod, few of these sections

are now satisfactory for study. The fossils of the Upper Maquoketa are found in thin, indurated, calcareous seams, well up towards the transition beds below the Niagara. The fauna is entirely distinct from that of the lower division. About a mile west of Kidder the fossiliferous slabs of this horizon are found in abundance on the sloping sides of the railway cuts, and the fauna here, as elsewhere, embraces such common Ordovician forms as branching monticuliporoids, *Plectambonites sericea*, *Orthis occidentalis*, *Orthis testudinaria*, *Rhynchotrema capax*, *Zygospira modesta*, *Tentaculites sterlingensis*, and *Ceraurus pleurexanthemus*. This fauna is essentially that of the Cincinnati shales of southwestern Ohio, and is not at all like that in the Graf and Hill's mill sections. *Plectambonites sericea*, *Orthis testudinaria* and *Ceraurus pleurexanthemus* were present in this area early in the Trenton; they seem to have disappeared from the region during the time represented by the later Galena and Lower Maquoketa; and then by migration they reoccupied these stations in Iowa, near the close of the Upper Maquoketa. The upper part of the Maquoketa, including the transition beds, is seen in the deep gorge known as Pine Hollow, in the northwest corner of the county, in Liberty township. The same beds, presenting the same characteristics, are seen at points along the Mississippi bluffs in the extreme southeastern part of the county, as well as in the hollows or gorges in the interior of Mosalem, the southeastern township. Reference has already been made to the exposures in sections 22 and 27 of Mosalem. It is in the Nw. ¼ of the Nw. qr. of Sec. 27, that the best section of the transition beds, noted during the progress of the present survey, occurs. Little more can be said of them than that the transition beds have a thickness of twenty-five feet; they are in non-laminated layers from two to six inches in thickness; they have a dirty, yellowish, clay color; and lithologically they are a rather soft, earthy or argillaceous, magnesian limestone. Fossils were not seen in

these beds in Dubuque county, but at Rockville, a short distance over the line in Delaware county, the beds are well shown on the east side of the stream below the milldam, and here the lower layers contain *Orthis testudinaria.* These beds of passage, or transition beds, are everywhere overlain by the basal ledges of the Niagara.

SILURIAN SYSTEM.

NIAGARA LIMESTONE.

The Niagara limestone, which follows the Maquoketa shales, occupies a larger area in the county than all the formations so far discussed, taken together. The Niagara is the youngest of the indurated rock series known to be exposed within the territory under consideration. The eastern margin of its area is very digitate, owing to the effects of long continued, chiefly preglacial, erosion. The drainage of the sloping sides of the great river valley cut great gashes down through this formation and deep into the underlying strata, and left finger-like extensions of the Niagara limestone running out on the summits of the higher ridges. The Niagara is, in the main, a heavy, yellow or buff colored dolomite. In its general characteristics it resembles the Galena limestone, and in many cases it could not be distinguished from the Galena without a knowledge of its fossil contents or its stratigraphic position. The formation is, however, not homogeneous; it varies in character to some extent at different levels; and beds occupying the same stratigraphic level differ more or less at different localities. Beginning with the lowest ledges of the Niagara, in contact with the transition beds of the Maquoketa shales, the somewhat arbitrary divisions which, as a matter of convenience, were recognized in the field, are: 1, Basal beds; 2, Lower quarry beds; 3, Chert beds; 4, *Syringopora tenella* beds; 5, *Pentamerus oblongus* beds; 6, Cerionites beds; 7, Upper quarry beds.

The basal beds are seen at numerous points in the valleys of the Little Maquoketa and its branches; in the valley of Catfish creek; in Pine Hollow in the northwest corner of the county; and in numerous unnamed gorges and ravines in Mosalem and Table Mound townships. The west end of the

Fig. 51. Train of blocks from the basal portion of the Niagara limestone creeping down slope occupied by Maquoketa shales. View taken in section 36, Iowa township.

dam at Washington Mills, in the southeast corner of Prairie Creek township, rests against characteristic ledges of the basal beds. At all points where these beds were seen in Dubuque county they consist of heavy layers, four to six, or even more, feet in thickness. As noted in the report on Delaware county, Volume VII of the present series of reports, the basal beds tend to split along lamination planes into relatively thin slabs. In general, however, the cohesion of the laminæ is so strong that masses of many feet in thickness retain their integrity even after undergoing tilting and displacement by reason of undermining brought about by weathering of the softer Maquoketa.

On all the gentle declivities occupied by the Maquoketa shales, between the Niagara escarpment and the top of the

Galena, great masses of the basal division of the Niagara, twelve feet or more in thickness, and not infrequently forty to fifty feet in length and as many in width, are seen in all positions gradually creeping down the long slopes. From year to year they come, inch by inch, as the insecure, mobile, slippery foundation gives way beneath their enormous weight. In places they occur in trains; very old, weathered blocks in the lead, with fresh, unweathered masses, but lately detached as a result of undermining, bringing up the rear. A part of such a train, half way down the slope, some of the blocks on edge and some in other positions, is shown in Figure 51, from a view taken in the Sw. ¼ of Sec. 36, Iowa Tp. In the Nw. ¼ of Sec. 21, Center Tp., there is a large mass of basal Niagara lying in the bed of the Little Maquoketa, at the base of a cliff of Galena limestone sixty feet in height. Here is a block which crept down the whole length of the Maquoketa incline and, at the bottom, tumbled over a sixty-foot cliff of Galena without undergoing complete destruction. The fact that some of these masses, which may attain dimensions of 100 feet or more, settle down without disturbing their horizontal position, adds to the difficulties of the geologist by presenting the deceptive appearance of native ledges of rocks in place. Still another source of error is found in the tendency of the soft, plastic, slippery beds of the Maquoketa to flow out, along steep hillsides, under the weight of the Niagara, and allow a body of limestone some scores of feet in thickness, and a half mile, or a mile, or even more, in length, to settle evenly without apparent displacement. An example of the bodily settling of what seems to be the whole mass of the Niagara, occurs along the Illinois Central railway, about a mile and a half northeast of Peosta. In the Se. ¼ of the Ne. qr. of Sec. 3, Vernon Tp., the railway at one point cuts through Maquoketa shales at a depth of seventy feet below the contact with the Niagara; and only thirty rods to the southwest, without essential change of level, the track enters a cut in the lower quarry beds of the overlying limestone. A mass of Niagara

of unknown length, and fully 100 feet in thickness, has here been allowed to settle, on account of flow of the soft shales, through a vertical distance of not less than eighty feet. This behavior of the Niagara whereby portions, particularly of the basal layers, are displaced without affecting their horizontal position, will probably account for the fact that Hall assigned to the underlying shales a thickness of less than seventy-five feet, and White a thickness of only eighty feet.

The characteristics of the Niagara as a whole, as well as of its several divisions, will be best understood by the consideration of a few typical sections. On the land of Z. Kidder, in the Sw. ¼ of Sec. 2, Taylor Tp., a small quarry has been opened in a situation which shows, in descending order:

		FEET.
5.	Chert beds consisting of coarse-grained dolomite in very uneven, thin layers, interbedded with a large amount of chert	4
4.	Lower quarry stone in courses varying from eight inches to two feet in thickness; stone light-gray to cream color, rather fine-grained, the upper layers carrying more or less of chert	14
3.	Basal beds in heavy layers which are, however, capable of being split along lamination planes into relatively thin divisions	12
2.	Transition beds of Maquoketa	13
1.	Plastic shale of the Upper Maquoketa; not measured.	

In the Nw. ¼ of the Sw. qr. of Sec. 36, Iowa Tp., there is a small quarry which shows:

		FEET.	INCHES.
6.	Coarse, worthless dolomite in very uneven and thin beds, interstratified with a large amount of chert; chert equaling or exceeding in volume the dolomite, broken into small, angular fragments; lower part of chert beds	12	
5.	Quarry stone in single course; with many nodules of chert	1	
4.	Moderately good ledge with some chert, caps into three or four layers	2	11
3.	Cherty, rather worthless ledge, a single course.	1	2
2.	Ledge of good quarry stone	2	4
1.	Good quarry stone	0	10

At the railway cut in the southeast quarter of section 3, Vernon township, in the great settled block of Niagara previously noted, the chert beds, with a thickness of twenty feet, are exposed in the upper part of the section, while the lower part shows ten feet belonging to the lower quarry beds and

Fig. 53. East Farley quarry showing the characteristics of the Lower Quarry beds of the Niagara limestone.

made up of courses ranging from three to fourteen inches in thickness. A few rods southwest, in the next quarter section, there is an opening showing the top of the quarry beds, above which the full thickness of the chert beds, twenty-five feet, is exposed. Near the base of the second member of the section at this locality there is about as much chert as limestone; farther up the limestone furnishes some usable layers, but the bedding surfaces are very uneven, and the limestone courses are still separated by very pronounced seams and nodules of chert. Above the chert beds at this point there are eight feet of coarse dolomite containing colonies of *Halysites catenulatus* and *Syringopora tenella.* On all the slopes on both sides of the valley, followed by the railroad in sections 3 and 10 of Vernon township, the coarse, imperfectly bedded and

practically useless beds of the *Syringopora tenella* zone are exposed above the chert beds up to the top of the bluffs.

The quarries in the vicinity of Farley illustrate well the characteristics of the lower quarry beds. The East Farley quarry (Fig. 52), worked by P. A. Milesi, is located in the southwest quarter of section 8, Taylor township. It affords the following section:

		INCHES.
8.	Coarse-grained bridge stone	21
7.	Stone of medium grade	28
6.	Ledge of fine-grained stone, with some chert	24
5.	Stone similar to number 6	14
4.	Fine-grained stone of good quality	4
3.	Stone of same quality as number 4	17
2.	Stone similar to 3 and 4	9
1.	Stone like 2, 3 and 4	26

Over the quarry stone there occurs, as waste or stripping, from one to three feet of decayed ledges, a foot or two of dark-colored residual clays which carry a large amount of chert, and three or four feet of drift and loess. Numbers 1, 2, 3, 5 and 6 furnish a good grade of dimension stone. The stone cuts easily, is fine-grained, light gray to light buff in color and tinged in places with streaks of iron oxide. Number 7 is worked for bridge stone.

The North Farley quarries are owned and operated by Mr. B. N. Arquitt. They are located in the southeast quarter of section 6, Taylor township, and have been worked more or less continuously for forty years. The several courses here are essentially the same as at the East Farley quarry. Certain courses which are single in one part of a quarry may be divided elsewhere, and layers which may be "capped" are estimated as single courses in one place, and as two or more separate courses in another. The usable quarry layers at the Arquitt quarries are overlain by three or four feet of residual clays and cherts, below which are four to twelve feet of decayed chert beds, and a solid, cherty ledge three and a half feet in thickness. The quarries are equipped with a number of derricks, the usual quarrying tools, horse-power hoists, and

steam sawing and rubbing machinery. The courses quarried below the stripping are:

		INCHES.
9.	Thick course used for cellar rock and rip-rap	36
8.	Heavy course used for bridge rock	24
7.	Bridge rock	24
6.	Bridge rock	16
5.	Cherty layer, furnishes some good material	18
4.	Coarse, cherty in places, but sometimes furnishes very good stone	14
3.	Coarse with some chert, used for cellar walls	12
2.	Stone of excellent quality, easily sawed to requisite dimensions	16
1.	Bottom ledge of good quality, caps along certain planes, easily sawed	26

As in all other exposures of the lower quarry beds, the courses are here separated by shaly partings, and the stone is a soft, easily worked, light-colored dolomite. The present demand for bridge stone taxes the output of the heavier layers, but were the conditions of the market different, numbers 6, 7 and 8 could be easily worked into rubble and dimension stone. The full thickness of the chert beds is developed in the hills which rise above the quarries to the southward.

The beds of the lower quarry horizon are exposed at so many points that it would be unprofitable to refer to them all. They may be seen and studied wherever erosion has revealed this part of the geological column, whether in the bluffs and walls of the ravines of Mosalem and Table Mound townships, or in the charming and picturesque gorge in the northwest part of Liberty. The beds increase in thickness toward the northwest, but remain constant as to other characteristics. The quarries near New Vienna, in sections 5 and 9 of New Wine township, utilize the lower quarry beds. As compared with the more thoroughly dolomitized and crystalline strata of the Syringopora and Pentamerus zones, the beds of the lower quarry zone weather easily, for which reason they are rarely exposed in the natural cliffs. Furthermore the overlying chert beds break down quickly under the effects of the weather, the sharp, angular fragments to which the chert

layers are reduced constituting a large amount of indestructible talus material which effectually conceals the soft, evenly bedded quarry stone. It so happens, therefore, that it is only under somewhat unusual and very favorable conditions that the lower quarry stone is naturally revealed at all; but any one interested in quarry development can easily locate the zone desired and expose the layers by stripping away the waste material by which they are concealed.

On the west side of Lytle creek at Washington Mills, in section 36, Prairie Creek township, there are exposures in the hillside which, though not continuous, indicate clearly the order of superposition of the lower members of the complete Niagara section. Below the milldam a large spring issues in the bottom of the valley, at about the level of the water in the creek. In Clayton, Delaware and Dubuque counties springs are common near the line of contact between the Niagara limestone and the Maquoketa shales. The descending waters, stopped by the shales, flow out at the lowest point below their head at which they can find exit, in some cases above, and in others below the line referred to. This spring is almost at the exact level of the contact line. The west end of the mill dam at this point abuts against basal beds of the Niagara, which show fully twelve feet in thickness. The top of the basal beds forms the floor of a quarry which is worked a little higher up on the hillside and exposes sixteen feet of fairly regularly bedded quarry stone, the lower quarry horizon. Above the quarry stone, as usual, are beds rich in chert; but the thickness of the chert beds could not be definitely determined, owing to the fact that the slopes are covered with soil and other loose materials. Fifty feet above the stream there are outcropping ledges of coarse, crystalline dolomite suitable for lime burning, containing fine colonies of *Syringopora tenella* and *Halysites catenulatus*. The corals named continue up to an altitude of eighty feet above the creek; at ninety feet the beds contain *Lyellia americana* in place; and

immediately above the ninety-foot level the rocks contain casts of *Pentamerus oblongus.*

Near the northeast corner of section 22, Washington township, there are projecting ledges of Niagara containing *Syringopora tenella*, *Halysites catenulatus*, *Favosites favosus*, *Lyellia americana*, and an unnamed species of Lyellia with small visceral tubes. On the hillsides there are loose slabs containing *Pentamerus oblongus.* In the Sw. ¼ of the Nw. qr. of Sec. 27, Mosalem township, near King postoffice, the road follows a ridge from the crest of which the surface descends in both directions to the bottoms of ravines 180 feet in depth. On the steep slopes there are rock exposures containing Syringopora and Halysites at an elevation of 100 feet above the base of the Niagara, and a few loose fragments of limestone, near the top of the ridge, contain casts of Pantamerus. The crags projecting from the sides of Table Mound, as well as the undisturbed layers on the summit, contain Syringopora and Halysites; while in loose fragments, on the very crest of the mound, there are occasional casts of Pentamerus. The point is that in southeastern Dubuque county there are usually not less than 100 feet, and in some cases at least 125 feet, of Niagara below the true Pentamerus horizon. The *Syringopora tenella* zone includes a thickness of forty-five or fifty feet between the chert beds and Pentamerus beds, the name being derived from the most typical coral of this horizon. Along Elk creek, in Delaware county, the lower members of the Niagara have a greater thickness* than in the central and southeastern parts of Dubuque. Furthermore, the chert beds, if they exist there, are concealed, and the space they occupy was added, in the Delaware county report, to the *Syringopora tenella* beds.

Near the southwest corner of section 32, White Water Tp., there are prominent crags and vertical cliffs of Niagara which yield the following section:

*Geology of Delaware county, Iowa Geol. Surv., Vol. VIII, p. 148. Des Moines, 1898.

		FEET.
11.	Light-colored, fine-grained rock resembling the upper quarry beds	2
10.	Soft, yellow, easily decomposed dolomite; Cerionites beds	4
9.	Moderately hard, yellow dolomite, with *Cerionites dactylioides*, *Caryocrinus ornatus*, *Eucalyptocrinus crassus*, *Pentamerus pergibbosus* and *Bronteus laphami*	5
8.	Soft, fine-grained, gray dolomite; Cerionites beds	15
7.	Coarse, massive dolomite, standing in vertical cliffs; *Pentamerus oblongus* horizon	45
6.	Hard, very compact dolomite, with many casts of Pentamerus, and some chert	5
5.	Soft, rapidly weathering, light-gray beds, with *Pentamerus oblongus* and non-silicified corals	2
4.	Moderately soft, rapidly weathering dolomite, containing the same corals found in number 3	7
3.	Hard, dark-gray beds, with many colonies of *Favosites hisingeri*, *Halysites catenulatus*, *Syringopora tenella*, and *Heliolites interstinctus*; all the corals are silicified; a good lime-burning rock	8
2.	Coarse, granular, light-buff dolomite, weathering irregularly and showing definite bedding planes; silicified corals, as in number 3	20
1.	Slope to level of water in stream, rock not exposed	20

In the above section numbers 2 to 4 belong to the *Syringopora tenella* beds; numbers 5 to 7 represent the zone of *Pentamerus oblongus*; 8, 9 and 10 are the Cerionites beds; and number 11 may possibly represent the upper quarry horizon. A short distance west of the cliff described, near an old limekiln, the Cerionites beds are exposed at the same level as in the cliff. Here they contain Favosites like *F. favosus*, *Caryocrinus ornatus*, a species of Stricklandinia, *Ambonychia acutirostra*, a slender, elongate Murchisonia, a large Straparollus, the annulate siphuncles of Oncoceras, and *Bronteus laphami*, besides the typical species, *Cerionites dactylioides*. A few rods southwest of the old limekiln referred to there is a large quarry opened in the hillside. The face of the quarry extends for a distance of 300 feet, and it exposes a section of about twenty feet. Beds 5 and 6 of the detailed section run through the middle of the quarry, the casts of *Pentamerus oblongus* being exceedingly common. The stone is of medium quality, the layers ranging from four

to twenty inches in thickness. About a mile west of the points just described, in the bank of the river below the mill at Cascade, there are ten feet of beds corresponding to number 2 of the section last described, below which are six feet belonging to the chert beds. The mill is located at a natural fall in the North Maquoketa river. Above the falls the floor of the channel is made up of a few feet of the rather hard, crystalline beds of the Syringopora zone. The underlying chert beds tend to weather and crumble and recede faster than the harder and purer dolomite above them; and thus there is brought about here, on a modest scale, the conditions of resistant beds underlain by rapidly crumbling strata, on which falls in streams so generally depend.

In section 36, White Water township, White Water creek flows in a steep-walled gorge 170 feet in depth. Near the bottom of the gorge and coming down to the level of the water in the stream, there are heavy, crystalline, hard beds containing *Halysites catenulatus*. Steep, inaccessible cliffs alternate with sodded slopes up to a height of 145 feet above the water, in which space are included the upper part of the Syringopora zone and all of the Pentamerus and Cerionites beds. One hundred and forty-five feet above the stream there is a small opening in the upper quarry beds from which quite an amount of valuable stone has been taken. The rock is evenly bedded in layers three to eight or ten inches in thickness, fine grained, cream to light buff in color, and contains the flat variety of Pentamerus which is characteristic of this horizon. The stone used in building Saint Martin's church at Cascade, was taken from this quarry.

In sections 31 to 36 of Cascade township, there are numerous exposures which repeat at varying heights the members of the section seen east of Cascade, in section 32 of White Water township. Along the stream in the Ne. ¼ of Sec. 30, Cascade, there are cliffs forty feet in height, embracing parts of the same section. At Hillside mills in section 18, the valley of the Maquoketa river is 150 feet deep, and the rocky cliffs in

the walls of the gorge show Pentamerus and Cerionites beds almost up to the level of the upper quarry horizon. A small quarry is opened in these upper beds in the Se. ¼ of Sec. 15, Cascade Tp., on land of P. Kremer; another quarry at the same horizon is located on land of J. Gearhart, in the Sw. ¼ of Sec. 4; and there is still another in the upper quarry beds near the northwest corner of section 5. In all the quarries in the central and northern part of Cascade township, a large proportion of the stone is thin-bedded and suitable for flagging; but there are not wanting heavier courses ranging from ten to fourteen inches in thickness to furnish desired material for all grades of range and rubble work.

A short distance from Dyersville, in the Se. ¼ of Sec. 32, New Wine Tp., there are quarries which work thin-bedded limestone more suitable for flagging than for any other purpose. The beds are unfossiliferous; a few decayed specimens of *Ptychophyllum expansum* were, however, seen in the refuse. There is another quarry in coarser and thicker beds, about the middle of the line between sections 5 and 6, Dodge township. The last quarry is probably below the level of the thin, flagging stone near Dyersville. The stratigraphic relations of the beds at the two points mentioned can not be made out, and owing to this fact, and to the absence of diagnostic fossils, it is not possible to state definitely the horizon to which they belong. It is probable, however, that they are part of the Syringopora zone. For in the northern part of the county, as, for example, near Balltown, Jefferson township, the chert beds are followed by ten feet of limestone in rather heavy layers, above which there are eight to ten feet of thin-bedded material like that in the quarries near Dyersville. The thin beds are more resistant than the heavier beds below, and in weathered cliffs they form projecting cornices as shown in Figure 53. The presence of flagging beds in the position they occupy in Jefferson township, together with the specimens of Ptychophyllum referred to above, supports the conclusion that the Dyersville quarries are in the Syringopora horizon.

This conclusion receives further support in the fact that there is a small quarry working somewhat similar material known positively to belong to the Syringopora beds, in the Sw. ¼ of the Ne. qr. of Sec. 27, New Wine Tp.

The outcrops of the Niagara in the beautiful gorge of Hollow creek, in the northwest corner of Liberty township, give rise

Fig. 53. View taken near Balltown in Jefferson township, showing, in the upper part of the cliffs, the flagstone beds of the *Syringopora tenella* zones.

to many picturesque castles and towers and flying buttresses which afford keen delight to all visitors who are capable of being impressed with natural grandeur. A short distance south of the north county line the sides of the gorge rise almost vertically for 300 feet, and a gentler slope carries the rim fifty feet higher. The base of the Niagara is here about 125 feet above the bottom of the valley, and well up the sides there are unscalable, vertical cliffs of the massive dolomite, eighty feet in height.

Exposures of Niagara limestone are very numerous throughout all the area west of the Niagara escarpment. Those above noted have been chosen for record simply because each is typical of many others, and all together they afford a comprehensive view of the Niagara as a whole. A few specific

cases of characteristic outcrops, not included in the general conspectus given in the foregoing pages, may still be worthy of mention. Northwest of Epworth, a ravine which nearly coincides with the line between sections 10 and 11 of Taylor township, shows, in descending order, the chert beds, lower quarry beds and basal beds of the Niagara, together with transition beds and plastic clay beds of the Upper Maquoketa. The basal and quarry beds are exposed along Lytle creek, near the northwest corner of section 29, Washington township, while chert beds overlain by some thin flagging occur one-half mile east of the creek. In the Nw. ¼ of Sec. 21 of Washington, there are exposures of massive Niagara belonging to the Pentamerus beds. At this point the shells of the Pentamerus are partly preserved, a somewhat unusual occurrence in dolomitic limestone. This phenomenon has been noted elsewhere in Iowa in only a few instances, the most striking example being found in the quarry east of Earlville in Delaware county. Associated with the Pentamerus in Washington township are *Favosites hispidus*, *Halysites catenulatus*, and *Heliolites megastoma*. Along Curran creek in section 35, Taylor township, there are high cliffs of Niagara embracing the upper part of the Syringopora, and the lower part of the Pentamerus beds. The rock is here imperfectly dolomitized, very coarse, irregularly bedded, and much weathered in pits and seams as now exposed. Fossils are scarce, but *Halysites catenulatus*, *Cannapora annulata*, *Heliolites interstinctus*, and *Pentamerus oblongus* were observed. The massive, coral-bearing beds of the Syringopora zone, with Halysites and other typical genera, are quarried a few rods south of the Dubuque county line, in the valley of the small creek west of Zwingle. The same beds crop out north of the road, in Dubuque county. A very coarse-grained rock containing small colonies of Halysites occurs in the walls of gorges cut by branches of Lytle creek, in section 33 of Table Mound township. In the Se. ¼ of Sec. 30, Iowa Tp., on land belonging to Mr. J. H. Tutt, there are a number of good exposures showing Pentamerus

beds with a thickness of nearly forty feet, below which are hard, heavy, crystalline strata of excellent qualilty for lime-burning. These lower rocks have the bedding planes largely obliterated and show in a typical way the characteristics of the thoroughly dolomitized portions of the Syringopora zone.

From the field notes and observations on which the foregoing descriptions are based, the following generalized summary of the Niagara section may be deduced:

		FEET.
7.	Upper quarry beds	20
6.	Cerionites beds	25
5.	Pentamerus beds	50
4.	Syringopora beds	65
3.	Chert beds	25
2.	Lower quarry beds	20
1.	Basal beds	15
	Total thickness of the Niagara limestone in Dubuque county	220

SUPERFICIAL MATERIALS.

In Dubuque county, as in nearly all other portions of the land surface of the globe, the indurated rocks are overlain by loose, unconsolidated materials which are products of rock disintegration. These loose materials constitute the soils and subsoils of the region in which they occur. They differ among themselves very greatly in respect to their history and genesis. Some were produced in the exact places where they are now found, by the slow, atmospheric decay of rocks similar to those upon which they lie. In many cases the soil materials have been produced by the disintegration of rocks in localities remote from the places they now occupy. They may have been transported for longer or shorter distances by flowing water, by moving ice, or by the action of the wind. Transported they have been in some way or other. The untransported soils, the soils formed in place, are made up of:

Residual Materials or Geest.—Through the chemical and mechanical action of air and water all exposed rocks are, and ever have been, undergoing a process of slow decay. The work of rock disintegration is hastened by the presence of

carbon dioxide, or other active adventitious gases in the air; or of the organic acids produced by decay of organic matter in the waters with which the rocks are in contact. The product of rock decay is an assemblage of incoherent particles of various sorts, which may accumulate by the progressive downward action of the process to depths of many feet. All the soluble constituents of the rocks which have suffered destruction, are likely to be carried away by the percolating waters, and the remaining insoluble, *residual* materials not infrequently undergo complete chemical and mineralogical change. For these reasons the resulting products quite generally bear little resemblance to the rocks from which they were derived. The different kinds of residual products seen in Dubuque county will presently be noted. These products are not assigned to any definite geological age, for the reason that rocks have been decaying, and residual materials have been forming ever since the county, at the close of the Silurian or early in Devonian time, rose above the sea.

In the county under consideration the residual materials derived from the decay of either the Saint Peter sandstone, or the Trenton limestone as limited by the definition of the Trenton on preceding pages, are small in amount and need not be here discussed. The residual products of the Galena limestone take the form of very dark brown or red, ferruginous clays which may be mixed with more or less of chert. But little of the Galena residuum, however, is seen at the surface. The formation has contributed only an inconsiderable amount of material in this county to the formation of soils, and that for the reason that the Galena is not here a surface rock over any very large area. But underground, where some might think it was protected from the atmosphere, it has been eaten away by the agents of rock disintegration; great caverns have been formed by destructive waste; and the brown, or red, or ocherous clay found in the crevices, and known as "crevice drift," is the resulting product. Of this product but little could have been known but for the conditions which

have led to the exploration of every fissure and cavern, so far as they have been located, in the search for mineral wealth.

The largest areas in the county in which the Galena may be regarded as the surface rock, occur in the valley of the Little Maquoketa and its branches, in Dubuque, Peru, Center, and Jefferson townships; and here there are occasional exposures of dark, ferruginous, residual clays among the constituents of the superficial materials. A good illustration is found in one of the railway cuts, a mile and a quarter northeast of Graf, where dark brown geest, to a thickness of three or four feet, is seen resting on weathered and partly decayed Galena. In the city of Dubuque, on Wood street, west of West Fourteenth, there is a bed of very dark residual clay, three feet in thickness, lying on the Galena and overlain by six feet of yellowish loess.

The residuum from the Maquoketa is the product of weathered shales. It is a clay differing less than is usual with residual materials from the beds from which it has been derived, and forming the inorganic part of much of the soil and subsoil of the region in which the Maquoketa formation occupies the surface.

The most extensive and the most conspicuous body of residual materials in Dubuque county is that which has been derived from the Niagara limestone. It forms an almost continous sheet over the whole of the large area in which the Niagara is the formation of indurated rocks lying nearest to the surface. While within this area, residual materials have doubtless been carried from the surface, along crevices, to great depths, and while they must have been produced, as in the case of the Galena, by waste and decay resulting from the widening of fissures and the formation of underground caverns, the body of such materials, which we know from actual observation, lies on top of undecayed Niagara and usually underneath beds of loess and drift. The residual products of the Niagara consist of dark, ferruginous clays with which is usually mixed a greater or less amount of chert

reduced to angular fragments. In localities where the chert beds—number 3 of the general Niagara section—have suffered disintegration, the residuum consists of a small amount of clay filling the interstices of chert fragments packed together as closely as the pieces of broken stone in a macadamized street. Where roads traverse such an area they are provided with a natural macadam, an example of which occurs in the northeast quarter of section 35, Center township. Other examples of the same kind are by no means uncommon, and exposures of geest derived either from the chert beds or from portions of the formation containing less siliceous material, are almost as numerous as sections of the superficial deposits showing contact with the underlying Niagara limestone. At one or two points in section 21 of Concord township, the residual clays and cherts of the Niagara attain a thickness of six feet, and a similar bed, three feet in thickness, occurs near the center of section 16, Vernon township.

During the very long interval between the elevation of Dubuque county above sea level, and the advent of the glacial conditions which spread a mantle of drift over almost the entire surface of Iowa, the exposed Niagara limestone suffered decay to an extent which cannot now be fully determined. The loose products resulting from this decay, however, were subject to the effects of erosion, and a very large proportion of them was carried away by flowing water. With the oncoming of the glaciers, which transported and distributed the first sheet of drift, such residual products as still remained upon the surface were more or less disturbed, and their materials, to a certain extent, were worked up and mixed with the detritus carried by the moving ice. Still it is true that the glaciers which passed over the surface left the old residual products intact to an extent which, to any observer, is a constant source of surprise.

PLEISTOCENE SYSTEM.

KANSAN DRIFT.

The Kansan drift is the oldest of the Pleistocene deposits positively recognized in Dubuque county. In the remarkably interesting and complete series of well records gathered by McGee* as a result of years of energetic research, there are some indications of a pre-Kansan drift. For example, a well located in the Se. ¼ of the Nw. qr. of Sec. 21, Iowa Tp. (well 67, p. 522 of the work cited) is recorded as showing: "Loess, six feet. Coarse yellow clay slightly assorted above, four feet. Soft tenacious blue clay, twelve feet. Dark soil containing woody fragments and ferruginous nodules, with a marshy odor, two feet. Finer tenacious blue clay with a few pebbles, eight feet. Water flowed in from the forest bed, and was so foul that the well was abandoned." The above record admits of the following possible interpretation: The coarse yellow clay beneath the loess, weathered Kansan. The twelve feet of soft blue clay which follows, unweathered Kansan. The soil with woody fragments and marshy odor, horizon of Aftonian forest bed. The lower eight feet of tenacious blue clay, pre-Kansan drift. Similar records indicating the existence of a sheet of till or bowlder clay beneath a definite soil or forest bed, are presented by wells numbered 86, 90, 97, and 113 in the work referred to. If more extensive sections than those afforded by isolated wells were available for study, it is possible that the facts might require some different hypothesis for their explanation; but the well records referred to are perfectly consistent with sections in the interior of the state, which very strongly indicate the existence of a till older than the Kansan, and separated from the Kansan by a time interval sufficient to permit of the growth of forests and the development of a well defined band of soil.

The sheet of till which geologists in recent years have been

*Pleistocene Hist. of Northeastern Iowa, by W J McGee. Eleventh Ann. Rep., U.S. Geol Sur., pp. 521-528. Washington, 1891.

agreed in calling Kansan, is, at all events, fairly well developed over all the portion of the county lying west and southwest of the margin of the driftless area. The Kansan drift is usually overlain by loess. Normally, beneath the loess, it shows (1) a weathered zone ranging up to six or eight feet in thickness, much oxidized and sometimes quite ferruginous, reddish or brownish near the upper surface, but becoming yellow at no very great depths; and (2) blue, unaltered till, the thickness of which depends on the amount of drift present at the point under observation. The yellow zone may blend somewhat gradually into the blue; and narrow, yellow, weathered bands may descend along joints in the blue till to depths of ten or fifteen or twenty feet. The unaltered, blue Kansan is usually quite calcareous, but in the upper part of the oxidized zone calcareous material is absent, the normal lime constituent having been removed by long exposure to the weather. The surface of the Kansan drift in Dubuque county had suffered the usual amount of erosion before the deposition of the loess. Complete drainage was developed, and this involved the carving of a dendritic system of water courses which branch and re-branch, and finally terminate on the higher uplands, in shallow draws, broadly V-shaped in cross section. The profile of such a surface consists of a series of convex curves, with the summits of the swells, at a distance from the larger drainage courses, rising to the level of the original undulating surface of the drift as it was left when the glaciers which deposited it retreated. The topography of the Kansan area, essentially as the surface appears at present, was fully developed before the loess was laid down; for this later deposit forms a relatively thin sheet more or less evenly spread over an erosion-carved system of hills and trenches which, if the loess were stripped off, would depart but little from the contours and reliefs of the present surface.

The Kansan till seems originally to have been a tenacious blue clay carrying a large amount of powdered limestone. The upper zone, however, has been altered in color; oxidation

and weathering have developed the reds, and browns, and yellows which now distinguish it. The zone has also been altered in composition; by the leaching effect of descending ground waters it has lost its calcareous constituent. In both the altered and unaltered Kansan, limestone pebbles and nodules are not uncommon. Northern bowlders are numerous, but they rarely attain a size exceeding two or three feet. There are some granites, and many of these, in the weathered portion, have become softened and decayed. Greenstones are common; and striated greenstone bowlderets may be regarded as among the most characteristic constituents of the Kansan till. Quite as interesting and almost as characteristic are the battered, frayed and splintered fragments of trees, which are distributed promiscuously throughout a thickness of many feet in the lower part of the drift sheet we are considering. The land, prior to the advent of the Kansan ice, was heavily forested; and the forest material, crushed and broken and abraded by resistless glaciers, was worked up into the drift and mingled with the waste and ruin of countless rocky ledges over which the ice sheet had passed. The old soils and humus beds of the pre-Kansan forests were very frequently left undisturbed, as is nowhere better shown than in McGee's splendid series of well sections previously noted.

The eastern margin of the Kansan drift is approximately indicated on the Pleistocene map which accompanies this report. That the line marking the boundary between the drift and the driftless area is absolutely correct, is not claimed; but, in general, it does not deviate from the extreme position occupied by the edge of the Kansan ice by more than one mile. Along the line referred to, the topography undergoes an abrupt change. On one side there is the eroded drift plain, with miniature hills and valleys cut in loose, superficial materials, just such a plain as characterizes the Kansan area throughout all the southern part of the state; on the other side are the deep trenches cut in indurated rocks, and all the other topographic forms and features of the driftless area. The

Kansan drift is greatly thickened toward its margin, forming a sort of morainic belt, which has, however, been much softened and subdued by long-continued erosion. The best opportunity to see the thickened margin is in the railway cut a short distance east of Peosta. Here there are at least thirty feet of typical Kansan till, blue and unchanged toward the base of the cut, but showing the effects of weathering near the original surface. This thickening of the drift at the margin gives rise to a fairly well defined ridge from which the surface slopes both ways. The descent to the driftless area is abrupt, and is accomplished in a short distance; that to the westward is more gentle, and the slope eventually blends imperceptibly into the general Kansan plain. By reference to the map it will be seen that the drainage of this part of the county is, on both sides, away from the marginal ridge.

The thickness of the Kansan drift is very variable. At many points west of the margin, in some cases within less than a mile of the thick morainic ridge, the trenches and rain-washed gullies in fields and along waysides show no trace of drift, except probably a few pebbles of crystalline rocks mixed with the local cherts and residual clays. The loess rests directly on residual materials. On many of the slopes within the Kansan area, both till and loess, if they were ever present, have been removed by erosion, leaving only some small northern bowlders to indicate that an ice sheet had ever occupied the region. Kansan till impresses itself on the observer following the ordinary wagon roads, at scores and scores of points where recent rainwash has cut through the overlying loess. As seen under such conditions the ordinary aspect is that of a very red, ferruginous, pebbly or sandy deposit. It is only the most altered upper part of the formation which is thus seen. The effects of long preloessial exposure to the atmosphere is expressed in the removal of the fine clay from the superficial zone and the segregation of the coarser sand and pebbles, as well as in the

processes of ferrugination, oxidation, and leaching which have been previously noted.

Buchanan Gravels.—While the Kansan ice was melting away, and torrents of water flowed out over the recently bared surface of the drift which the ice relinquished as it receded, large quantities of clay, sand, and gravel were carried by the turbid floods and deposited along the drainage courses where, for any cause, the impetus of the currents received the necessary check. The materials so carried and deposited were sorted in accordance with the laws governing transportation and deposition by flowing water, and the beds into which they were finally built up were more or less regularly stratified. In the latitude of Dubuque county and northward the accumulations referable to this particular episode in the history of glacial conditions, are composed of coarse materials, largely of gravel mixed with quantities of sharp quartz sand. From their great development in Buchanan county, these accumulations have been called the Buchanan gravels. Buchanan gravels are among the conspicuous Pleistocene deposits of the county we are now considering.

Owing to their permeability to air and moisture, the Buchanan gravels are usually very much weathered and oxidized; and they are sure to attract attention by reason of their red tints and rusty ferruginous appearance near the surface. Cross-bedding is one of the common characteristics of the deposits, which, together with the coarse nature of the material, is indicative of deposition from strong currents. A few rods south of the postoffice at Peosta, the wagon road cuts through a low ridge which shows from two to four feet of rusty beds of water-laid sand and gravel of Buchanan age, overlain by four feet of loess; and on the eastern slope of the thick marginal ridge of Kansan drift, three-fourths of a mile east of Peosta, there is a very typical bed of these gravels on the south side of the railway track. A bed of the gravel, rather sandy and somewhat modified by erosion, is seen a rod

or two south of the railway crossing, near the station at Epworth. A short distance northwest of Epworth, in the Sw. ¼ of the Nw. qr. of Sec. 10, Taylor township, sixty feet below the level of the railway track, recent erosion has cut a deep gully in stratified sands and gravels of this age. This last exposure is somewhat unique in the fact that a part of the water-laid deposits here associated with the Buchanan gravels is a fine drab clay. There are two layers of the clay separated by a band of reddish sand. Usually the finer silts transported by the muddy streams from the melting Kansan ice were not deposited within the limits of the territory under investigation. They were carried farther southward, but the beds to which they have given rise have not yet been specifically recognized. Another exposure of the gravels in Taylor township occurs about one-fourth of a mile south of the northwest corner of section 3. In Cascade township exposures of Buchanan gravels are not uncommon. It will be sufficient to mention a pit worked quite extensively for road material a short distance northeast of the center of section 16, another a short distance north of the southeast corner of section 22, a fine exposure in the southwest part of 22, and another near the center of section 28. The gravel bed in section 16 is a part of a low ridge rising slightly above the surrounding surface; it is worked to a depth of six feet, is very ferruginous and rusty, shows the bedding planes well, and includes, with pebbles of foreign origin, a considerable amount of local chert. Gravel ridges of the kind described are met with occasionally; they may represent kames or eskers instead of an outwash from the margin of the melting ice. Other occurrences of the gravels simply repeat the phenomena already described.

Kansan Outwash in the Driftless Area.—Within the driftless area, well out from the margin of the Kansan drift as this is traced on the accompanying map, there are occasional Kansan bowlders from a few inches to a foot or more in diameter,

together with accumulations of ferruginous materials resembling the Buchanan gravels. Some of the bowlders and gravel deposits are found on comparatively high ground; but, most naturally, the outwash from the Kansan ice margin followed the drainage courses. A Kansan bowlder, ten or twelve inches in diameter, lies by the roadside, on a high plateau, in Mosalem township; and there is quite a large body of ferruginous, gravelly material, with cobblestones of Kansan type, on the comparatively high ridge followed by the road in Dubuque township, a short distance east of Julien. Near Table Mound, in the Sw. ¼ of Sec. 11, Table Mound Tp., there are numerous pebbles of northern, crystalline rocks mingled with the thin layer of residual materials underneath the loess. In general, however, the Kansan outwash is to be sought in the valleys of such streams as head well up toward the Kansan margin. Trains of gravel and bowlders seem to have been strewn along the Little Maquoketa valley from a short distance below North Farley to the mouth of the stream, but only a few remnants of these deposits have escaped subsequent erosion. The valley of Catfish creek has some deposits of this age, and so has the valley of Grange creek. In the valley of Grange creek, in the Ne. ¼ of Sec. 23 and adjacent parts of 13 and 14, Table Mound Tp., there is quite a large deposit of very characteristic Kansan material.

The time of transportation and deposition of the outwash referred to probably coincided with the time of maximum development of the Kansan ice. The streams of the driftless area at this time afforded the only outlet for the drainage waters resulting from the continual ablation of the ice, and the same conditions must have persisted for some time after rapid melting and actual retreat of the glaciers began. These eastward sloping valleys were accordingly taxed to their capacity with turbid floods; and sheets of water, loaded with detritus from the Kansan drift, doubtless flowed out over even the higher levels before being gathered into definite streams. Pebbles and well rounded bowlders are known, in many

instances, to have been carried for long distances by simple sheet water action, and the presence of outwash in even the higher parts of the driftless area need excite no surprise.

IOWAN DRIFT.

The interval which followed the withdrawal of the Kansan ice and the deposition of the Buchanan gravels was certainly long if counted in the ordinary units of time; but its duration is only imperfectly and indefinitely indicated,—by no means measured,—by the extent of the erosion, weathering, and leaching which took place during its progress in the exposed surface of the Kansan till. This interval was marked by fluctuations of climate due to the approach and withdrawal of the glaciers of the Illinoian age. In time, however, during what has been called the Iowan division of the glacial epoch, a depression of temperature brought about a renewal of glacial conditions, and Dubuque county was again invaded by glacier ice. During the Iowan stage glaciers were not developed in such force as during the Kansan; the terminal margin of the ice sheet, even when the glacial conditions of this stage had reached their maximum, lay for the most part west of the Dubuque county line; but a few narrow tongues of ice favored by certain low-lying tracts of land, flowed out from the margin, invaded the county, and occupied the small, peculiarly shaped areas which have been mapped as Iowan drift. The amount of Iowan till deposited in these areas is very small, but the areas are, nevertheless, readily distinguished by certain unmistakable characteristics. In the first place the surface is comparatively level, its inequalities are constructional, it has not been cut and carved and modeled in any way by erosion. In the second place the surface is not covered with loess; the rich black loamy soil which at once distinguishes it has been developed upon bowlder clay. Then again the surface is liberally sprinkled with large granite bowlders which, taken as a whole in all their aspects and peculiarities, are not duplicated by anything found in connection with the Kansan

till. The surface of the Iowan drift has not been leached or oxidized, nor have the Iowan bowlders suffered decay, to even approximately the same extent as may be noted in connection with the Kansan. The Kansan is relatively old; all the characteristics of the Iowan indicate newness. Where the body of Iowan till is fully developed, as in Buchanan, Bremer and Black Hawk counties, it is fundamentally a yellow clay rich in lime carbonate. It usually carries only a small number of pebbles and cobblestones, and all of these, practically, are fragments of northern crystalline rocks. Local limestones and cherts are rare in the Iowan drift. In Dubuque county the sheet of Iowan till, as has been said, is small in amount; so thin in fact that it has been quite completely modified by the growth of plants and converted into a dark carbonaceous soil.

The Iowan drift in Dubuque county is distributed in three relatively small areas, which, for convenience, may be designated, respectively, the Farley lobe, the Worthington-Bernard lobe, and the southwestern area. The southwestern area is part of a lobe in the northern part of Jones county, the outlines of which have not yet been traced. The space it occupies in our present territory is less than four square miles. The Farley lobe enters the county at Dyersville, trends southwest past Farley, and terminates in a number of lobules which interdigitate with loess-covered Kansan ridges south of Epworth. The southern lobule is continued into section 35 of Taylor township. The margin of the Farley

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lobe is very sinuous and irregular along its northeastern edge, owing, apparently, to the number of pre-Iowan hills, among which the motile ice became entangled, and which it was unable to overflow. Worthington is located near the beginning of the middle lobe of the Iowan ice which invaded Dubuque county. The width of the lobe was at first about three

miles. Its trend across Dodge, the northeastern part of Cascade, and on to near Fillmore, in White Water township, is about parallel to that of the Farley lobe. Northwest of Fillmore the ice seems to have been contracted to the limits of a narrow gorge through which it passed; and then, widening out, it flowed more nearly eastward past the site of Bernard into section 35 of Prairie Creek township. Evidences of the unusual motility and anomalous behavior of the marginal portions of the Iowan ice have been previously noted.*

Loess.—The fine, homogeneous, yellow silt, known as loess, covers practically the whole area of the county, except the small portions occupied by the Iowan drift, the Wisconsin terraces, and the more recent alluvium. The loess is superficial, therefore, over most of the Kansan area and the driftless portion of Dubuque county, and so has a wider distribution than any of the other Pleistocene formations. It is fresh, unweathered, and unleached, as compared with the upper surface of the Kansan drift and the Buchanan gravels, upon which it rests in the region west and southwest of the thickened Kansan border. It differs markedly in color and composition from the dark, tenacious clays and other residual products which it overlies throughout the driftless area. The age of the loess seems to coincide with that of the Iowan drift. There are reasons for believing that it was deposited while the Iowan ice was at its maximum development. It was not laid down, therefore, on Iowan areas, for at the time of its deposition these areas were still occupied by Iowan glaciers. By some agent or agents fine dust-like material, derived from the Iowan till, was distributed outward from the Iowan margin and spread as a thin veneer over the uneven, eroded surface of the extra-marginal territory. That wind was one of the agents concerned in the transportation and distribution of the loess is rendered highly probable by the researches of

*Report on the Geology of Delaware county; Iowa Geol. Surv., Vol. VIII, p. 172. *The Iowan Drift*, by Samuel Calvin; Bull. Geol. Soc. of America, Vol. X, p. 119.

Shimek, Udden, Wilder† and many others who have thoroughly investigated the problems involved. While the peculiar deposit in question is spoken of as a veneer covering the pre-loessial surface, it is true that it varies greatly in thickness in different localities, ranging in this respect from a few inches to more than thirty feet. It lies everywhere unconformably upon a surface which had previously been carved and moulded by erosion. It contains many fossils, among which the most common are shells of land snails belonging to species that may still be found living upon the surface. Near the Iowan margin the basal portions of the loess usually contain a considerable amount of sand. It would seem as if the first outwash from the edge of the Iowan ice consisted of a fine sand which was sometimes obscurely, and sometimes distinctly stratified; and that later the sand was overlaid with the finer dust or silt which makes up the typical loess. Except along the larger streams the sandy phase of the loess does not extend more than two or three miles from the border of the Iowan area. The main body of the loess is frequently obscurely stratified, the stratification in some cases being indicated only by alternating moister and drier bands.

WISCONSIN TERRACES.

After the deposition of the Iowan drift and the contemporaneous loess, northeastern Iowa, and the regions northward to an extent at present unknown, were freed from their mantle of ice and experienced the effects of the short Peorian interglacial interval. The Peorian interval was followed by the ice invasion of the Wisconsin stage, but the glaciers of this stage did not extend as far as Dubuque county. The main river valley, however, was occupied with Wisconsin ice in Wisconsin and Minnesota, and tributaries which enter the Mississippi not far above Dubuque had the upper parts of their drainage basins choked with advancing marginal portions of the great Wisconsin ice sheet. During the advance,

†See Wilder's report on Lyon and Sioux counties, this volume, pp. 121 and 145.

the culmination, and the final melting of this ice the Mississippi and its upper tributaries were flooded, and the torrential floods were loaded with detritus. As a result outwash sands and gravels of Wisconsin age are prominent along the Mississippi throughout Dubuque county. These deposits fill up the old valley to a depth of some hundreds of feet, and they form well defined terraces which show wherever there is a lateral enlargement of the valley. The widening of the valley afforded an opportunity for the existence of slack water in which deposition was possible. Dubuque proper is in part built upon a Wisconsin terrace, and the manufacturing establishments near the river draw their water supply from the sands and gravels of which it is composed. Easily studied examples of these terraces are found in many places. One of the best and most accessible is the sandy ridge between Rhomberg avenue and the river. This has been cut in many places in the process of street grading, and sections twenty feet or more in height, showing perfectly the definite banding and stratification of the materials, have thus been exposed. The gravel pits near Peru also show the terrace material to advantage; and deposits of the same age are well exposed near the point where the Illinois Central railroad turns away from the Mississippi into the abandoned portion of the valley of Catfish creek. The surface exposures of these deposits, both at Dubuque and over the Peru bottoms, yield gravels for road making, and sand for building purposes.

The Wisconsin terraces contain a large amount of foreign material, but along the tributary streams, away from the immediate vicinity of the Mississippi, foreign material is absent. In Wisconsin time the drainage seems to have been essentially as it is now. The flooding and filling of the main river channel caused back water in the tributaries, and the lower courses of these tributaries were accordingly filled with local material to the same height that the main channel was filled with foreign gravel and sand. Where an important

tributary appeared, large quantities of detritus were dropped by both streams; and, for example, at the mouth of the Little Maquoketa, the terrace rises sixty feet above the bottom land. In this locality the Wisconsin material forms a barrier which the tributary stream avoids by running north along the bluff to the Mississippi.

ALLUVIUM.

The term alluvium may be used for any material deposited on river flood plains. The terraces noted above are definitely referred to the Wisconsin age of the glacial epoch; but there are fluviatile deposits along the streams in the interior of the county, the age of which cannot be determined. Some may be older, some are certainly newer than the Wisconsin. There are true alluvial deposits along the North Maquoketa in Cascade township, and similar deposits occur along the Little Maquoketa and its branches wherever the valleys have been cut to grade and have been widened so as to produce a definite flood plain. Even along the minor drainage courses the stream valleys occasionally show small patches of alluvium. These are due to inequalities in the hardness of the rock, to the coming in of side streams, to changes of course, and similar factors. Upon the accompanying map these minor areas have not been discriminated; nor have the Wisconsin terraces proper been set off from the synchronous terraces of local material, or from the true alluvium.

SUMMARY OF PLEISTOCENE HISTORY.

Since the beginning of the Pleistocene it is probable that Dubuque county was three times invaded by glaciers, (1) during the pre-Kansan age, (2) during the Kansan, and (3) during the Iowan. During two of the recognized ages of the glacial epoch, the Illinoian and the Wisconsin, the county was not reached by the respective sheets of ice belonging to the intervals of glaciation. In both cases the glaciers did not come within many miles of the borders of the county, but their

influence on the climate must have been felt, and the Wisconsin terraces are permanent effects of the latest approach of glacial conditions. Five times the region suffered the rigors of an Arctic climate, and five times climatic conditions were ameliorated; the amelioration which followed the Wisconsin stage introduced the conditions now characterizing this part of the continent. The interglacial interval, the Aftonian, which preceded the invasion of the Kansan glaciers, was marked by the growth of forests. In these Aftonian forests the spruce and the larch were among the commonest of the trees, but according to the well records of McGee it is probable that trees with broad, deciduous leaves, such as the elm, were also present.

There is reason to believe that at the time of melting of the Kansan ice the surface of Iowa was at least as high as it is at present. At all events the drainage was energetic; and vigorous currents transported for long distances the coarse materials which were finally deposited to form the Buchanan gravels. The ice may have melted rapidly and so have given volume to the floods which swept out from the edge of the retreating ice over the recently bared surface, and in this way part of the energy of the drainage streams may be accounted for; but the evidence indicates a time of moderate elevation of the land, unimpeded drainage, and currents loaded with detritus. There are rounded rock fragments in the Buchanan gravels ranging from three or four, to eight or ten inches in diameter.

The melting of the Iowan ice evidently took place without giving rise to currents strong enough to carry particles larger than fine sand; and even this was not transported more than a very few miles except along the larger drainage courses. The materials carried outward from the margin of the Iowan ice make up the present fine-grained loess, and it is probable that wind may have been as efficient an agent as water in their distribution. It is probable that, at this time, the land stood much lower than now, and that the drainage was so

choked and sluggish that nothing but the finest silt was carried any great distance from the edge of the melting ice. The feeble character of the drainage may have been due in part to the fact that the ice was thin and that it melted so slowly as not to give rise to vigorous floods. Whatever the cause or combination of causes, the agents of transportation which operated in connection with the melting of the Iowan ice, carried only the very finest of materials.

The events which closed the Wisconsin glacial stage are in strong contrast with those which closed the Iowan. The culmination and departure of the Wisconsin glaciers were attended with floods greater and more energetic, even, than those of the Kansan—a fact very clearly attested by the enormous quantities of sand and gravel, fifty to a hundred feet in thickness, heaped up along all the drainage courses leading outward from the margin of the Wisconsin drift. These materials, becoming progressively finer, are strewn along the stream valleys for scores or hundreds of miles. Their volume and character are well illustrated by the Wisconsin terraces of Dubuque county, already described.

Calcareous Tufa.—Wherever springs issue, or have issued from the Galena-Trenton limestone, a certain amount of calcareous material is found deposited from solution. These chemical deposits are usually porous; but occasionally the pores are filled solid, and the product takes on the form of travertine. The presence of algæ, or of partially submerged mosses and liverworts, seems to facilitate the process of deposition by reason of the fact that the green plants quickly absorb the carbon dioxide, the presence of which gives to spring waters, in their underground courses, the power of taking up and holding carbonate of lime in solution. The lime is very frequently deposited as a thin crust on the stems of the plants, and some of the forms which it thus eventually assumes, are known as "petrified moss." Along the river bluffs from Eagle Point to Waupeton, calcareous tufa is a common characteristic, occurring in places in great masses several

feet in thickness, and everywhere cementing the shingle and scree and loose fragments of all kinds strewn over the face of the bluff, into a sort of tufaceous breccia. The process is still in operation. It has doubtless been active ever since the river channel was cut to any considerable depth, ever since spring water, in any volume and at any level, issued from the seams and fissures of the rocks and moistened the face of the bluffs. The deposit is probably all Pleistocene; some of it may be preglacial in age; some of it was formed but yesterday.

DEFORMATIONS.

The indurated rocks of Dubuque county have suffered deformation on a small scale. They have been subjected to enough of strain and lateral crushing to throw them into a series of low antielinal and synclinal folds, and the force was applied in such wise as to give the folds a general east-west trend. The folds may be studied to best advantage along the river bluffs, and one of the best localities occurs a mile or two above, and a mile or two below, Specht Ferry. Some of the anticlines are sufficiently striking to receive attention from persons going up or down the river on passing boats. The most pronounced fold is that which constitutes the Eagle Point anticline noted in connection with the description of the Galena limestone. The strains which resulted in the formation of folds gave rise to the joints and fissures and evidences of shearing which will be more fully discussed in connection with the occurrence of the ores of lead and zinc.

UNCONFORMITIES.

There are no evident unconformities between any consecutive formations of the indurated rocks in Dubuque county. The band of coarse materials above the top of the Galena limestone, and its probable significance, have been noted in discussing the Maquoketa shales. The Pleistocene deposits, however, are unconformable with the indurated rocks and amongst themselves. The pre-Kansan, if present, and the

Kansan certainly, if the older drift is absent, was laid down upon an eroded surface; the Iowan drift and the loess are unconformable on the Kansan; the loess even overlaps the indurated rocks of the driftless area; and the Wisconsin terraces are confined to old erosion valleys.

ECONOMIC GEOLOGY OF DUBUQUE COUNTY.

SOILS.

Dubuque county has, for an Iowa county, more than the usual variety of soils. The original soils were composed wholly of residual products, and in some parts of the driftless area the soils are yet largely residual. During the Iowan division of the Pleistocene the whole surface, outside the margin of the Iowan ice, received a deposit of loess of greater or less thickness, and loess soils are now by far the most common within the area we are considering. Loess is the most valuable of the soil materials in the vicinity of Dubuque and throughout the driftless area. Loess is a porous material permitting the free distribution of gases and moisture; it is quite calcareous in composition, and is, therefore, well adapted to the production of grasses and all kinds of grains. All varieties of fruits flourish well in loess soils. Within the driftless area the loess overlies residual products, or geest. The geest usually contains more or less of tenacious clay which tends to hold the moisture near the surface; and this moisture, in times of drought, is brought, by capillary action in the porous loess, within reach of the roots of plants. In the loess-Kansan area the soil is composed of loess overlying Kansan drift. On steep hillsides the loess washes badly, and the soils are consequently thin and poor. But in the regions of gently undulating loess-Kansan there is developed a brown, friable loam of qualities unexcelled for agricultural purposes. These regions are large, as has been noted in the section on topography, the surface is thoroughly drained, the conditions for successful farming are as favorable as could well be

imagined. The soil of the Iowan areas is, in general, a dark, rich loam upon which grasses grow luxuriantly, and corn, the staple crop of Iowa, does remarkably well. If any disadvantages are to be mentioned at all in connection with Iowan soils, they are to be found in the imperfect drainage of some localities, and in the further fact that, in places, the surface is encumbered with large granite bowlders. There are also some Iowan areas which are quite sandy, as, for example, sections 15, 16, 21, 22, and 25 of White Water township. But the level character of the Iowan surface is in striking contrast with the steep hills of the driftless areas, and with even the minor erosional irregularities of the loess-Kansan; and this gives it a great advantage in the facility with which improved agricultural machinery may be used.

In the forestry notes on the county, by Professor Macbride, there are many valuable and timely suggestions respecting the soils. In particular the waste of soils on the steep slopes of the driftless area and the manner in which such surfaces can be utilized to greatest profit are discussed in a manner deserving careful consideration.

LEAD AND ZINC.

HISTORICAL SKETCH.

The Dubuque mines have for the geologist and mining engineer a rare historical interest. They were the first of the upper Mississippi mines to be opened and among the first in America to be developed. In earlier years they were the most important source of lead in the world aside from the mines of northern England and of Spain. At one time they were considered far more valuable than the lower Mississippi or Missouri mines. Leadville and the other famous lead-silver mines of the west were then unknown. Iowa and the surrounding region was then "the west" and the Rocky mountains and the Cordilleras were not within the limits of practical exploration. As late as 1852 the Upper Valley

mines produced 13,000 tons of lead; 10 per cent of the world's production of that year and 87 per cent of that of our own country. That was a century and a half after the mines were first seen by white men and nearly half as long since the first attempt had been made to work them.

It was Le Sueur who in his voyage up the Mississippi in 1700, or possibly in an earlier voyage, first noted the presence of lead both in the upper and lower Mississippi valley. The Indians had doubtless known of the presence of this mineral before this, but it may be considered certain that they knew nothing of smelting until taught later by white men. Le Sueur's voyage did not result in any attempt to work the upper mines, though the presence of mineral in the vicinity was not lost sight of and was duly noted by Guettard* and the mines were located by Bauche on one of the earliest of geological, or rather as they were then called, mineralogical maps. The first attempt to work the mines of the Mississippi valley was made in Missouri. In 1820 the "Company of the West" organized in France by John Law, sent out Renault and La Motte, or La Mothe according to one spelling, and commenced mining in the Ozarks. The famous Mine La Motte was first opened at this time and has been worked more or less constantly ever since.

It was more than half a century later that the upper mines were first worked. According to Schoolcraft,* to whom we are indebted for the first published account of the Dubuque mines, the discovery of lead was made by the Indians themselves, as he states in the following paragraph:

"In 1780 a discovery of lead ore was made upon their lands by the wife of Peosta, a warrior of the Kettle Chief's village, and extensive mines have since been discovered. These were granted by the Indians to Julien Dubuque at a council held at Prairie du Chien in 1788, by virtue of which he settled upon the lands, erected buildings and furnaces, and continued to work the mines until the year 1810. In the meantime (1796)

*Histoire de l' Academie Royale, des Sciences, 1752, pp. 189-220.

*Schoolcraft, H. R., Narrative Journal of Travels, etc., Albany, 1821, p. 34?.

he received a confirmation of the Indian grant from the Baron de Carondelet, governor of Louisiana, in which they were designated the 'Mines of Spain.'"

Under Dubuque's regime several mines were opened up, though it seems that no shafts were sunk. The ore was obtained by means of the hoe, shovel, crowbar and pick from carelessly protected drifts. Good roads were, however, built to the furnaces, one of which was erected near the mouth of Catfish creek, where Dubuque had his house in Kettle Chief's village. It is stated that up to recent years the sites of two of Dubuque's furnaces were well known—one on Eagle Point avenue, near Heebs' Brewery, and the other between Main street and the river. Hon. M. M. Ham has given us† a graphic account of Dubuque and of his life among the Indians.

A visit to Dubuque was one of the objects of Lieutenant, later General, Pike's expedition up the Mississippi in 1805. He found M. Dubuque "polite but evasive," and did not visit the mines, although there is an interesting statement signed by Dubuque and Pike in 1805, in which it is declared that 20,000 to 40,000 pounds of lead were made per annum, that being a yield of 75 per cent. It is also stated that copper had at that time been noticed, though no attempt had been made to reduce it.

After Dubuque's death the Indians burned his house and fences and destroyed all traces of civilized life. They continued, however, to work the mines intermittently, selling the ore to certain Indian traders who were located on islands in the river.

Dubuque died in debt, but before his death he assigned his claims to his creditors, and out of this fact grew a controversy as to the possession of the property. The claims, however, were never allowed, the government taking the ground that both the Indians and the Spanish governor, Carondelet, gave to Dubuque simply permission to work the mines, and that this permission was personal to him. There was in the

†Annals of Iowa, Vol. II, Third Ser., pp. 329-344, 1893.

Spanish grant no provision for a survey of the land, nor were other forms customary in making a grant followed. Dubuque's original request for "peaceable possession of the mines" was merely indorsed, "granted as is asked (*concedido como sa solicita*)."

It was twenty years after Dubuque's death in 1810, that white men again attempted to work the mines. Certain miners from Galena, attracted by the reputed richness of the Dubuque mines, and acting under the authority of the Dubuque heirs, crossed the river and began work. It is said that the Langworthy crevice on Eagle Point avenue was opened at this time. The government held, however, that the country was not yet open to settlement, and troops from Prairie du Chien drove out the miners and burned their cabins. The development of the mines across the river had in the meantime been in progress, but for some years yet the Iowa mines were worked by the Indians. Schoolcraft in 1820* made a canoe voyage from Prairie du Chien to the present site of the city, at that time known as the Kettle Chief's Village. The main workings at that time seem to have been west of the river, although Schoolcraft enumerates, in addition to the Dubuque mines the "Sissinaway mines" and the "Mine au Fevre;" the former the prototype of the Wisconsin mines and the latter the earliest workings at Galena. What are known as the Durango diggings, then passed under the name of the Mine of Maquanquitons. Schoolcraft's description, the first which we have of the mines at Dubuque proper, is as follows:

> The district of country generally called Dubuque's lead mines, embraces an area of about twenty-one square leagues. Commencing at the mouth of the Little Maquanquitons river, sixty miles below Prairie du Chien, and extending along the west bank of the Mississippi seven leagues, commencing immediately at the Fox village of the Kettle chief, and extending westward. This is the seat of the mining operations formerly carried on by Dubuque, and of what are called the Indian diggings. The ore found is the common sulphuret of lead, with a broad foliated structure and high metallic lustre. It occurs massive, and disseminated, in a reddish loam, resting upon limestone rock, and sometimes is seen in small veins pervading the rock, but it has been chiefly explored in alluvial soil. It

*Schoolcraft, H. R., Narrative Journal of Travels, etc., Albany, 1821.

generally occurs in beds or veins which have no great width, and run in a certain direction 300 or 400 yards,—then cease, or are traced into some crevice in the rock, having the appearance of a regular vein. At this stage of the pursuit most of the diggings have been abandoned and frequently with small veins of ore in view. No matrix is found with the ore which is dug out of the alluvial soil, but it is enveloped by the naked earth, and the lumps of ore are incrusted by an ocherous earth. Occasionally, however, some pieces of calcareous spar are thrown out of the earth in digging after lead, and I picked up a solitary specimen of the transparent sulphate of barytes, but these substances appear to be very rare. There is none of the radiated quartz, or white, opake heavy spar, which is so common at the Missouri mines. The calcareous rock upon which this alluvial formation, containing lead ore, rests, appears to be referable to the transition class. I have not ascertained its particular extent about the mines. The same formation is seen, overlaid by a distinct stratum of compact limestone, containing numerous petrifications, at several places between the mines and Prairie du Chien. The lead ore at these mines is now exclusively dug by the Fox Indians, and, as is usual among savage tribes, the chief labor devolves upon the women. The old and superannuated men also partake in these labors, but the warriors and young men, hold themselves above it. They employ the hoe, shovel and pick-axe, and crow-bar, in taking up the ore. These things are supplied by the traders, but no shafts are sunk, not even of the simplest kind, and the windlass and bucket are unknown among them. They run drifts into the hills so far as they can conveniently go without the use of gunpowder, and if a trench caves in it is abandoned. They always dig down at such an angle that they can walk in and out of the pits, and I descended into one of these which had probably been carried down for forty feet. All this is the work of the Indian women and old men, who discovered a degree of perseverance and industry, which is deserving of commendation. When a quantity of ore has been gotten out, it is carried in baskets by the women to the banks of the Mississippi, and then ferried over in canoes to the island, where it is purchased by the traders at the rate of $2 for 120 pounds, payable in goods sold. At the profits at which these goods are usually sold it may be presumed to cost the traders from 75 cents to $1, cash value, per 100 weight. The traders smelt the ore upon the island, in furnaces of the same construction used at the lead mines of Missouri, and observe that it yields the same per centum of metallic lead. Formerly the Indians were in the habit of smelting their ore themselves, upon log heaps, by which a great portion was converted into what are called lead-ashes, and thus lost. Now the traders induce them to search about the sites of the ancient fires, and carefully collect the lead ashes, for which they receive $1 per bushel delivered at the island, payable in merchandise.

As early as 1821 something was done in Wisconsin and Illinois by the white miners, but it was not until 1827 that mining really became active. From that time the development of the Illinois and Wisconsin mines was uninterrupted except by the Black Hawk war. The history of these years in Iowa is summarized by Dr. Leonard as follows:*

* Iowa Geol. Survey, Vol. VI, p. 16.

At the close of the Black Hawk war, the large tract known as the Black Hawk purchase, including one-third of the present area of Iowa, was ceded to the United States by the Sacs and Foxes. After the completion of the treaty negotiations, the miners again crossed over into the coveted region, where they built cabins and commenced to take out much ore. But a second time they were forced to leave because the treaty had not been ratified. In June, 1833, the treaty went into effect and the way was at length clear for settlers to take possession of the land. During the next few years large numbers flocked in, prospecting was actively carried on and many mines were soon in operation.

A superintendent of mines was appointed by the government and a system of permits to miners and smelters was adopted. For some years the smelters were required to pay 6 per cent of all the lead produced. This tax was the cause of much dissatisfaction and was abolished at the end of ten years.

The first "legislation" in Iowa dates from 1830. In June of that year a number of miners met on the banks of the Mississippi and enacted regulations to govern them in their relations to each other. One of the articles was that "every man shall hold 200 yards square of ground by working said ground one day in six." Much other interesting early history clusters around these mines but it is foreign to our purpose to go into that phase of the subject here.

Aside from the historical interest the mines are worthy of study from the fact that it was here that some of the elemental ideas as to ore deposits were worked out. It was in the study of the Dubuque mines that "gash" veins were first discriminated and in the latest text-books, both of this and foreign countries, they are still cited as the type. Whitney, in his writings on the region, made what is in many particulars the first complete application of the theory of lateral segregation to the origin of ore deposits. Previously a deep-seated source had been almost universally assumed as *a priori* the more probable. Since the mines were first worked our ideas of ore deposits and many of our conceptions of geology in general have radically changed, and it is well to keep this in mind in reading the earlier accounts of the region.

In the first description of the mines published, Schoolcraft, who was a careful and painstaking observer, refers the country rock of the region somewhat vaguely to the "transition" period. This indefiniteness of reference arose less from lack of observation than of precision in ideas.

It is a little difficult at times to remember how recently the science of geology has come into being, and in re-reading the

descriptions of the mines left us by various investigators up to the middle of the present century, it is important to remember how much our ideas of geology and of ore deposits have changed. It was only in 1807 that the Geological Society of London was organized, and a serious attempt was made to substitute observation for theory in geology. It was as late as 1818 that the first number of the *American Journal of Science* was published in New York, and in the first interesting number of that journal* it is said that "geological researches are now prosecuted by actually examining the structure and arrangement of districts," and the accent was evidently intended to be placed upon the word "now." It is important to keep in mind the mental atmosphere in which the first explorers lived in order not to give undue value to their theoretic beliefs as to the origin of the ores.

As has been seen, a visit to Dubuque was one of the objects of Pike's expedition up the Mississippi, but the first strictly geological exploration was not undertaken until 1836, when G. W. Featherstonhaugh, having visited the year before, the mines of Missouri, was employed by the general government to make a reconnoissance in the northwest. In the course of the work he visited the upper mines, but in his report there is little of value.†

When the mines were first developed the government adopted a plan of leasing them, but owing to difficulties in securing the payment of these royalties it eventually became necessary to sell the lands. Preliminary to this a survey was ordered in 1839, and placed in charge of that pioneer western geologist, D. D. Owen. This survey was in many particulars unique. The field work was begun in September and, with the aid of a large number of assistants, was finished before winter; a report, accompanied by maps, sections, figures, descriptions and fossils, being submitted to the Land Office on the second of the following April. This report was

*Page 7.

†Report of a Geological Reconnoissance made in 1835 from the seat of government, by way of Green Bay and the Wisconsin territory, to the Coteau de Prairie, p. 158, Washington, 1836.

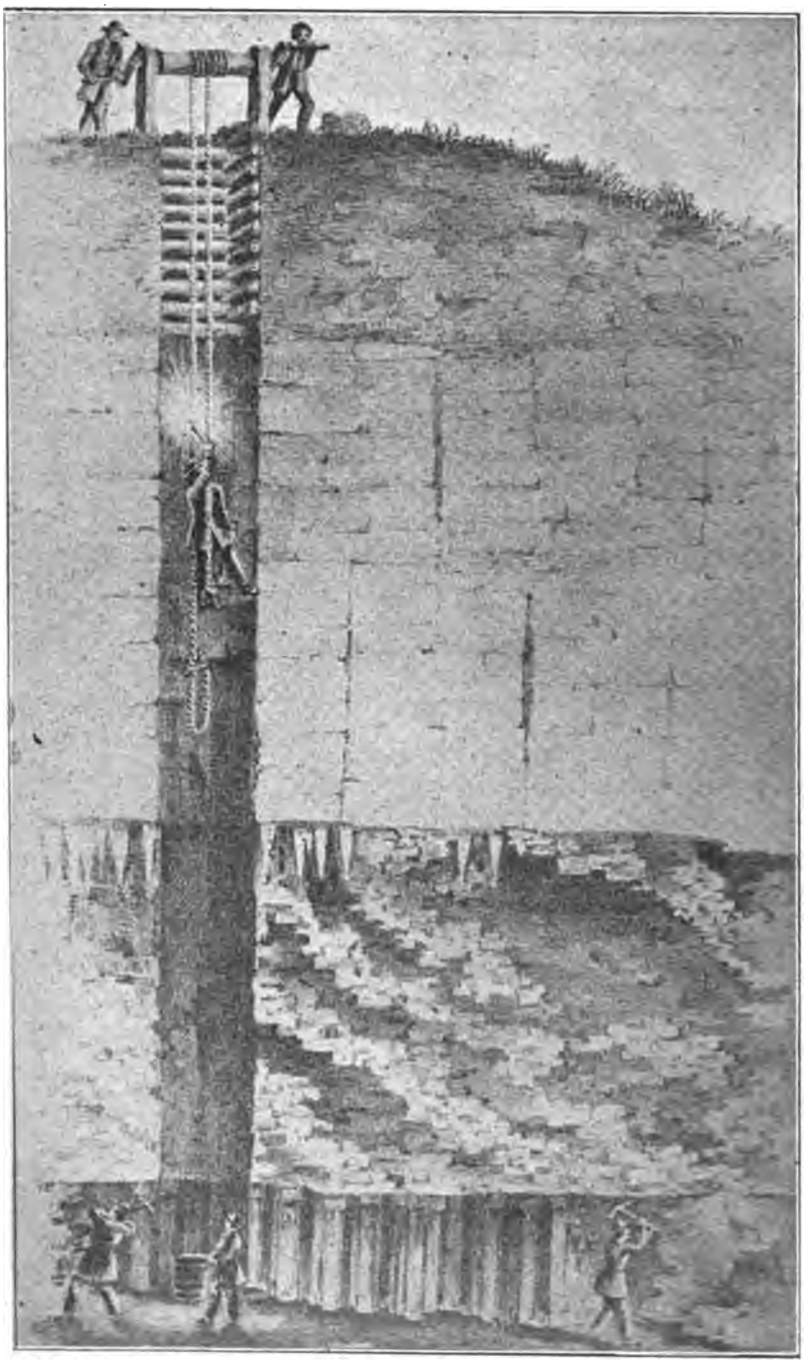

PLATE VI. Copy of illustration drawn by D. D. Owen, and published in his report on work done in autumn of 1839. Probably the earliest published illustration of the process of lead mining in the Dubuque district. Practically the same methods are now in use.

printed without illustrations* in June of the same year, and a revised edition, including the omitted plates, was printed in 1844.† In this survey a large area, including the whole of the mining section, was traversed township by township, and the character of the rocks was noted. An estimate of its geologic value is given elsewhere in this paper. In 1847 Owen executed for the Treasury Department another survey of the Chippewa Land District, and in his report on that region‡ gives certain additional details regarding the lead and zinc region.

In the course of a still later survey he visited the region again and in his well known quarto report there is a brief discussion of the geological formations present.§ Owen was accordingly the first geologist of note who studied the region in detail, and his conclusions, based as they were upon a long and intimate acquaintance with it, are worthy of the utmost respect. It is curious to note, however, that he entirely overlooked the Maquoketa shale and confused the Galena and Niagara; and it can be readily believed that in this, as well as in his opinions respecting the deep seated origin of the ore deposits, he was misled by the ideas then current and accepted.

In 1854, J. D. Whitney, than whom no one has done more correctly to interpret the phenomena of the region, published his Metallic Wealth of the United States.‖ Having made certain investigations in the region in the course of his private professional work, he gave a very accurate though brief account of the mines. His ideas were later elaborated in the course of his work for the three states, Iowa, Wisconsin and Illinois, for which he successively studied the field. In his reports on these states he covers the whole ground excellently, and it is no disparagement to others to say that

*House Rep. Exc. Doc., 26th Cong., 1st Sess., No. 239, 161 pp., Washington, 1840.
†Rept. Geol. Exp. Iowa, Wis., Ill., made in autumn 1839, Washington, 1844.
‡30th Cong., 1st Sess., Sen. Ex. Doc., No. 57, 134 pp., Washington, 1848.
§Rept. Geol. Surv., Wis., Iowa and Minn., 638 pp., Philadelphia, 1852.
‖Philadelphia, Lippincott, Grambo & Co., 1854.

together his reports form the best and most complete account of the field ever published.*

Professor Whitney's report is extensively quoted elsewhere in this paper. He visited the region in the years of the maximum importance of the lead mines and his observations are accordingly particularly valuable. It was, however, after his work was finished that zinc became of value in the region. Industrial conditions have also largely changed so that there is now much of interest to be added to his report.

Aside from Whitney and Owen, the best known of the earlier investigators in this region was Percival, who in 1854 and 1855 made a study of the lead region for the state of Wisconsin. Accuracy of observation is everywhere characteristic of Percival's work, but his conclusions as to the origin of the ores and the best methods of working them seem to have been unfortunate.† Like Owen he followed the current theory of the period. Blake has recently shown, however, that Percival was the first to recognize correctly the presence and importance of faults in the region.

The later Wisconsin survey renewed the study of the region and in the elaborate papers of Strong‡ and Chamberlin§ we have much the most detailed study of the region extant, with, in the latter case, a notable addition to the discussion of the theoretic considerations involved.

The fall in the price of silver and the consequent closing of many of the lead-silver mines of the west led renewed attention to be directed to the soft lead deposits of the Mississippi valley. The most notable contribution to the literature of the subject resulting was the report on the lead and zinc deposits of Missouri by Winslow and Robertson‖ published in 1894. While nominally devoted to the Missouri field

*Geol. Iowa (Hall), Vol. I, pp. 286-295, 423-471, Albany, 1858. Geol. Wis. (Hall), Vol. I, pp. 73-424, 1862. Geol. Ill., Vol. I, pp. 153-207, Springfield, 1866.

†Percival, J. G., Ann. Rept. Geol. Surv. Wis., 101 pp., 1855. (Second) Ann. Rept. Geol. Surv., Wis., 111 pp., 1856.

‡Geol. Wis., Vol. II, pp. 643-752, 1877.

§Geol. Wis., Vol. IV, pp. 365-571, 1882.

‖Lead and Zinc Deposits by Arthur Winslow assisted by James D. Robertson. Missouri Geol. Surv., Vols. VI and VII. Jefferson City, 1894.

the report covers practically the whole subject, and there are quite full notes on the upper mines though nothing original is attempted in the latter field. The meeting of the International Engineering Congress at Chicago in 1893, and the reading there of Posepney's famous paper on the origin of ore deposits, led, directly and indirectly, to the publication of a number of papers in which the phenomena of the region are discussed. Among the more important, with others of the same period, are those of Posepney*, Jenney†, Blake‡, Winslow,§ Robertson‖, Chamberlin¶, and Roethe**.

Since the organization of the present survey considerable attention has been devoted to the study of the lead and zinc region. Dr. A. G. Leonard prepared a preliminary report upon the lead and zinc mines of the state which was published in 1896.†† He also published several short papers on the same subject.‡‡ Calvin,§§ has made a study of the mines in the lower Magnesian or Oneota dolomite, and since the present work began brief notes have been published in Mines and Minerals‖‖ and the Mineral Industry.¶¶

GEOLOGY.

The general geology of the region has already been sufficiently described in an earlier portion of this report. It remains but to emphasize certain points which are believed to have especial significance in connection with the origin and distribution of the ore bodies.

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* Posepney: Trans. Amer. Inst. Min. Eng., Vol. XXIII, pp. 197-369; XXIV, p. 207.

† Jenney; Ibid, Vol. XXII, pp. 171-225.

‡ Blake; Ibid, Vol. XXII, pp. 558-568, 569-574, 621-646, XXIII, 587. Bul. Geol. Soc. Amer., Vol. V, pp. 25-32. Trans. Wisconsin Acad. Arts. Sci. Let. Dec., 1892; Amer. Geologist, Vol. XII, pp. 237-248.

§ Winslow; Trans. Amer. Inst. Ming. Eng., XXIII, pp. 528-529. Jour. Geol. Vol. I, pp. 612-619.

‖ Robertson; Amer. Geologist, Vol. XV, pp. 235-248.

¶ Chamberlin; Bul. Geol. Soc. Amer., Vol. V, p. 32.

** Roethe: Eng. Min. Jour. Vol. LX, pp. 88-89.

†† Lead and Zinc Deposits of Iowa, by A. G. Leonard, Iowa Geol. Surv., Vol. VI, pp. 9-66.

‡‡ Eng. Min. Jour., Vol. 61, p. 614; Amer. Geologist, Vol. XVI, pp. 288-294: Proc. Iowa Acad. Sci., Vol. I, pt. IV, pp. 48-52, Ibid, Vol. II, pp. 36-38, Ibid. Vol. III, pp. 64-66.

§§ Iowa Geol. Surv, Vol. IV, pp. 103-107.

‖‖ Bain: Mines and Minerals, Vol. XX, No. 1, pp. 10-12.

¶¶ The Mineral Industry, Vol. VIII, pp. 636-638, New York, 1900.

In general the rocks of the region consist of a series of sedimentaries including limestones, dolomites, shales and sandstones. The rocks exposed within the limits of the county form only a portion of a larger series, in part now buried and so not open to observation, and in part removed, so far as this particular area is concerned, through the process of erosion. The rocks which underlie the oldest rocks exposed in Dubuque county may be studied in Allamakee and Clayton counties, Iowa, and in adjacent portions of Wisconsin. They consist essentially of alternating sandstones and dolomites belonging to the Cambrian and Lower Ordovician formations. The most important of these buried dolomites is the Oneota, or as it was formerly called the Lower Magnesian limestone. These underlying sediments rest upon a still older series of rocks, probably largely metamorphic in character, and only reached in Iowa in the deepest drill holes. These metamorphic rocks seem to have formed, in early Cambrian time, a land mass around the southwest flank of which the lead-bearing rocks, with the accompanying barren beds, were deposited.

Saint Peter Sandstone.—The lowest rock exposed in the county is the Saint Peter sandstone, a porous, friable, water-bearing rock which never shows any signs of mineralization. It is exposed along the base of the bluffs from the mouth of the Little Maquoketa, north, dipping to the south. There can be no doubt that it underlies the whole of Dubuque county, in fact it has been penetrated in the deep wells of northeastern Iowa so frequently as to preclude any possible doubt of its continuity and uniform character throughout the region.* It is significant from the present point of view that the Saint Peter, though cut by innumerable streams and exposed over many square miles of Iowa and adjacent states, has never at any point been shown to be mineral-bearing. The only possible exception to this statement is the case of the Crow Branch diggings in Wisconsin, where mineral was

*Norton: Artesian Wells of Iowa, Iowa Geol. Surv., Vol. VI, 181, 202 *et seq.*

found running down to the sand rock, and has been reported to have run into it.* In this case, however, it was apparently a merely local instance of an upper ore body following a crack down into the sandstone. It was essentially similar to the occurrence near Lansing of several thousand pounds of mineral in the top of the St. Croix sandstone at the base of an important crevice through the Oneota. The Saint Peter is a barren formation, and, furthermore, is not characterized by either crevices or caves, though the latter do occur.†

In the second place the Saint Peter is an important source of artesian water throughout Iowa. A large number of wells in the eastern part of the state derive their supply in whole or in part from this formation. This water is under pressure and seeks to rise through any opening driven down to it. It is usually charged with certain salts which are characteristic, and which enable the water from this horizon to be readily recognized. An analysis of characteristic water from the Saint Peter is given below:

ANALYSIS OF WATER FROM MONONA WELL.*

*Norton: Iowa Geol. Surv., Vol. VI, p. 188.

	GRAINS IN U. S. WINE GALLONS.
Calcium carbonate	7.14
Magnesium carbonate	8.95
Calcium sulphate	10.41
Alkaline sulphates	.63
Alkaline chlorides	1 87
Silica, alumnia, and oxide of iron	.10
Total	29.10

A majority of the artesian wells of the region draw their supply not only from this but from lower sandstones belonging to the Cambrian. The water derived from these wells is, however, all strongly mineralized and very characteristic. The fact, however, that the analyses from particular horizons are characteristic and that the pressure is distinct from each horizon argues against any general connection between these different

*Whitney: Geol. Wisconsin, p. 363.
†Calvin: American Geologist, Vol. XVII, pp. 195-203.

water-bearing horizons; that is, there is no general set of open crevices running down through them or from one to the other.

Galena-Trenton.—Before discussing in detail the various members of this group there are certain questions relating to the series as a whole which may be noted. As has already been shown the Galena-Trenton is made up of dolomite, dolomitic limestone and non-magnesian limestone, with a very subordinate amount of shale or clay. In a general way the major and upper portion is more or less completely dolomitized and to it the name Galena limestone is applied. The lower portion consists of an upper, non-magnesian blue limestone, and a lower magnesian rock known usually as the lower buff beds. All of these members are commonly found throughout the area of outcrop of the series as a whole. Except for the intervention of a few feet of shale, the lower buff beds rest directly upon the Saint Peter sandstone and maintain a quite uniform thickness of approximately twenty-five feet throughout the region. Above them is the blue, non-magnesian limestone. It has already been pointed out that the thickness and character of this member varies considerably in various portions of the field. In Allamakee county it reaches a maximum of 150 feet and is made up of alternating layers of shale and shaly limestone.* In Dubuque county it is rarely more than twenty feet in thickness. The Galena limestone, which reaches a maximum of 237 feet in thickness at Dubuque, is represented by less than fifty feet of strata in Allamakee county. At both extremes a thin bed of shale is found between the base of what is called the Galena and the top of the recognized Trenton. Careful tracing up the river indicates, however, that it is not the same shale from point to point but that each of the shale beds which in Allamakee county divide the Trenton series, in turn marks off the Galena from the Trenton as one travels south and toward lower stratigraphic horizons. Certain of the beds, which are usually particularly fossiliferous, can be

*Calvin: Iowa Geol. Surv., Vol. IV, pp. 75-78.

traced literally from the Trenton into the Galena. In general, however, when one passes from the non-dolomitized into the dolomitic rock, the shales disappear. The general conclusion already stated is inevitable, viz., that the difference between the Galena and the Trenton is not formational. It is also obvious that the rock has been dolomitized to an increasing depth toward the south, and that this increasing depth of dolomitization varies *parri passu* with a decreasing amount of shale in the formation. Further study shows that in each point the base of the overlying dolomite is separated from the underlying non-dolomitized rock by a bed of shale and that dolomitization proceeded from the top downward and was stopped at successively lower horizons toward the south as the various shale beds thinned out.

The older Archean and Cambrain land from which the material of the Galena-Trenton series was derived, lay undoubtedly to the north and east of the district under consideration. The major portion of the sediment deposited here came apparently from the north. The shales are made up of mechanical sediment. They indicate nearness to land and the progressively slighter southern extent of the later shale beds indicates merely the gain of the sea over the land and the pushing of the shore line to the north. Whereas at the beginning of the Galena as defined at Dubuque, the shore was so near the latter point that clay and fine mud could be deposited over the region, at its close the shore had retreated so far that mechanical deposition had almost entirely ceased, not only at Dubuque but over a wide region to the north. Chemical and organic agencies were accordingly prominent in the formation of these later beds. It remains to inquire in detail what these agencies were and how they acted.

Neither limestones nor dolomites are formed, with unimportant exceptions, through mechanical means. They must either be the result of primary or secondary chemical action.

Taking first the case of limestones, but little study is necessary to show that while it is possible that they may be formed by direct chemical precipitation from a saturated solution or by the action of springs, as a matter of fact most limestones seem to have been formed through various organic agencies. A large number of animals have the power of secreting lime from sea water to form the various hard parts of their bodies, and these shells and other remains, in part broken up by the waves and possibly recemented by percolating water, later perhaps recrystallized into a homogeneous mass, make up the bulk of known limestones. The limestones of the region under consideration afford, so far as can be discovered, no exception to this rule. It is further clear that they were formed within relatively shallow water since they were still within the reach of an occasional incursion of mud.

The rocks now dolomitized were manifestly deposited under somewhat different circumstances. It is clear that they were not within the limits of mechanical sedimentation to any appreciable extent. Certain considerations also make it clear that the rocks as originally deposited were not dolomitic, though not necessarily non-magnesian, and that the change to dolomite has been a secondary process. It is not intended, however to affirm that this change may not have followed immediately after the deposition or even have been in part contemporaneous with it, but merely that there was an appreciable, though not necessarily long, pause in the general process. The considerations upon which this is based are briefly as follows:

The uniform stoppage of dolomitization at a shale band when traced downward, is a striking, though not necessarily conclusive, confirmation of the main thesis. Shale is far more impervious than either limestone or dolomite, and the shale bed makes always a break in either downward or upward water flow. It thus exerts an important influence on all secondary reactions taking place in stratified rocks, though it does not have any determining value in the matter of primary sequence.

A shale bed might be a valid reason for dolomite above and limestone below if we believe the dolomite to be altered limestone, but it would be of no significance if we assume the latter to have been originally deposited as a dolomite.

The non-dolomitic rock is characteristically thin bedded, and the thin bedded rocks of definite horizons on the one side are represented by the thick bedded on the other. Either some change has taken place which has led to the obliteration of the bedding planes, and has given the rock a new and massive character, or for some peculiar reason these planes were never developed in the southern portion of strictly contemporaneous beds, though conspicuous in the same beds farther north. The most convincing evidence, however, of the essentially secondary nature of the dolomite is derived from the manner of preservation of the fossils in the two parts of the deposits.

It is evident, then, that a considerable portion of the magnesia now present in these rocks was not deposited as a carbonate, but that its change into this form is a later one. This does not exclude the hypothesis that a considerable portion of the magnesian carbonate may have been originally deposited as such. It is known that both magnesia and calcium are in solution in sea water in small but appreciable amounts, and it is believed that the magnesia may under certain conditions be deposited directly as a carbonate. Constantine Klement has shown by experiment* upon the action of solutions of magnesian salts on powdered aragonite and calcite that a mechanical mixture of magnesium and calcium carbonates could be produced. He subjected powdered aragonite crystals and coral to the action of magnesium sulphate in a concentrated solution of sodium chloride. Action began at 60° and increased to 91°, with a maximum yield of 42 per cent of magnesium carbonate, which, in the presence of calcium carbonate, gradually crystallized as a true dolomite. It

*Bul. Soc. Geol. Belge., 1895, 9, 3-23, Tscher Mitth., 1895, 14, 526-544; Abstract. Jour. Chem. Soc., LXX, II, 116.

is to be noted that these conditions would all be readily reproduced in shallow sea basins, such, for example, as the enclosed lagoons of atolls. This is in line with what has been actually observed in coral atolls.

In enclosed basins of sea water magnesium chloride is often in considerable excess over the sodium chloride.† The evaporation of the sea water tends to make the solution continually stronger, so that there is a constantly increasing tendency for the magnesia to enter into combination with the limerock which may be believed to form the basin of the pool in question, and to have been deposited mainly, as usual, through the action of living organisms. Soft, newly formed sediments may readily be believed to be particularly open to changes induced by the presence above them of relatively strong solutions, and Sterry Hunt has shown that a number of chemical reactions are probable, through which the change to dolomite can be brought about.

It is believed that in some such manner as this the newly formed non-dolomitized Trenton rock was changed into the dolomitized form now known as Galena. Chamberlin has shown that the beds in question were laid down in water so shallow as to be within the limit of wave action,* and while no such clear evidence has been observed in Iowa, certain breccias occur which are best explained by a similar hypothesis. It is also significant that the dolomitic Galena is followed and covered by the Maquoketa shale which is formed from mechanically derived sediment. Furthermore at the base of the Maquoketa is the bed of small pebbles already described. These show clearly the action of surface agencies, but the fact that no Archean material has been found among them indicates that the pebbles were in the main locally derived. All the conditions are just such as would be expected when the sea gradually disappeared over a wide, flat expanse

†Geikie, 3rd Ed., p. 412.
*Geol. Wis., Vol. IV, p. 409.

by simply drying up, and when sedimentation was resumed without great change in the altitude of the land.

The phenomena in hand seem, then, to be best interpreted upon the supposition that during the accumulation of the beds now known as the Galena the area was occupied by a broad, shallow, land-locked basin or series of basins over which evaporation was active. This evaporation necessarily had the effect of concentrating solutions which in normal sea water are dilute. That this action was discontinuous and that its operation was unequal at different times and in different parts of the area, is obviously the most reasonable supposition, and consequently at different levels and in different areas we may expect to find varying degrees of evidence of this sea water concentration. As a matter of fact this is true and there are all varieties, from the most perfect dolomite to limestone with but a small percentage of magnesia.

A detailed section of the Galena-Trenton series has already been given and it has been indicated that the lead and zinc ores are confined to this formation. Later the different ore horizons are noted but it seems important here to note certain features of the overlying formations.

Maquoketa.—The formation which immediately overlies the Galena is the Maquoketa shale or "slate" as it is commonly known among the miners. This is in large part a soft argillacous shale. It is a barren formation, no mines ever having been worked in it, nor have any important bodies of ore been found in it. In one or two instances only, in sinking through the slate, small pieces of ore a fraction of an inch in diameter have been found. In view of the fact that the shale is composed of mechanically prepared material, and that at its base pebbles of pre-existing rocks of various sorts are common, these bits of ore can be quite certainly considered to be adventitious in origin. The miners' conception of them as float is a good one.

The shale is not cut by any general system of crevices. Such cracks as occur in it are close set and of small extent.

Fracture in it has taken the form, as would be expected from its semi-plastic nature, of many small cracks rather than a few well developed ones such as mark the dolomitic beds. The shale accordingly is a practically impermeable horizon and cuts off the ordinary surface waters above from the limestones below. There is no general circulation of water down through the shale into the Galena limestone. The water which is found in the limestone comes from the collecting area over which the dolomite is itself exposed, or from those areas which, by the arrangement of the divides, shed surface water upon the area occupied by the Galena. The water runs over the slate rather than through it.

Niagara.—Above the Maquoketa is the great thickness of Niagara which, like the Galena, is dolomitic. There are, however, important differences. The Niagara is normally finer grained and does not seem to be as much cut up by crevices and caves as is the Galena, though it lies higher above the water level. The Niagara shows occasional traces of lead, though no paying mines have ever been developed in it. In Jones county, near Anamosa, at Clinton, and at Sherril Mound in Dubuque county, small quantities of lead have been found. In this particular, the formation is like the Oneota, in which ore has been found in small quantities at several points, though only the one mine at Lansing has ever been developed. So far as analyses of the rock are concerned, the Niagara is not notably richer or poorer than the Galena, and the absence of ore bodies may probably be considered to be due to some defect in the matter of concentration.

THE ORE DEPOSITS.

ORES AND ASSOCIATED MINERALS.

The ores found in Dubuque county include lead, zinc, a small amount of copper, and at least one notable deposit of iron. The latter will be separately treated, but the others may be considered together. Lead and zinc are the only minerals being actively mined at present. The following notes

on the minerals occurring are revised from Dr. Leonard's report.*

The only ore of lead that is found to any extent in the Iowa mines is the sulphide, galena (Pb S). The carbonate, cerussite (Pb CO_3), is of rare occurrence, and is derived by alteration from the more common sulphide.

Galena (Lead, 86.6 per cent; sulphur, 13.4 per cent; Sp. gr. 7.4–7.6).—This mineral occurs, as a rule, in well defined cubes, which are joined together in masses of greater or less size, forming groups or aggregates of crystals. The corners of the cube are sometimes replaced by the faces of the octahedron, and this form may predominate until, in rare cases, the cubic faces have disappeared altogether. All the specimens observed from the mines directly about Dubuque were clusters of cubes unmodified, but the Galena from a section lying south of the city, as well as that from the Guttenberg mines, is crystallized in forms showing the combination of the cube and octahedron. From the last mentioned locality a few unmodified octahedrons were obtained.

The crystals seldom present bright metallic surfaces, the faces being dull and more or less corroded or coated over with some foreign substance. The miners have different names for the various kinds of lead ore. Thus the term "cog mineral" is applied to groups of good sized cubic crystals. When these are small the ore is called "dice mineral." When the sulphide occurs filling a narrow fissure, it is rarely well crystallized, and is then known as "sheet mineral," and when occurring in irregular masses it is called "chunk mineral."

The lead from the Iowa mines, like that from the other regions of the Mississippi valley, contains only a trace of silver, and is known as soft lead in contrast with the argentiferous ore of the western mines. More or less of silver is almost invariably present in lead ore, especially when the latter is

*Iowa Geol. Surv., Vol. VI, pp. 25-27.

found occurring in the neighborhood of metamorphic or igneous rocks. But the deposits found in undisturbed sedimentary strata commonly contain no silver except in very small amounts.

Dr. Otto Kuntze, of Iowa City, has recently brought to

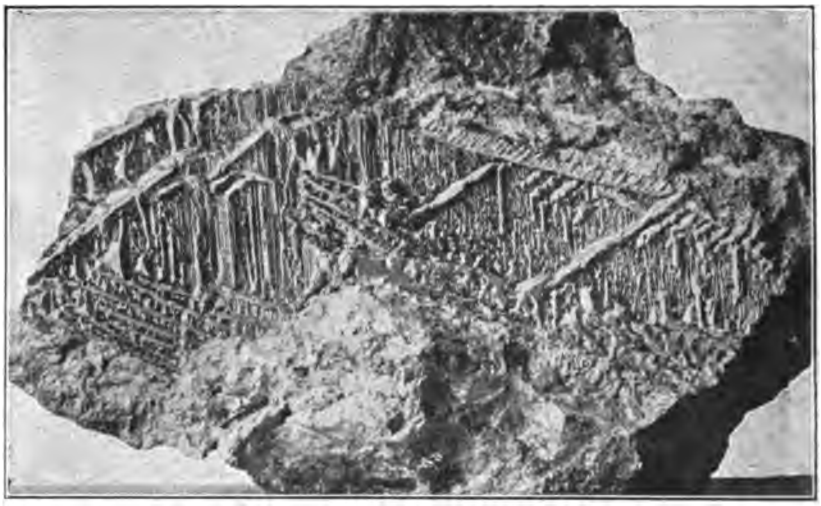


Fig. 54. Reticulated Galena. Three-fifths natural size, from collection of Dr. Otto Kuntze.

light some exceptionally good specimens of reticulated forms of Galena, one of which is illustrated in figure 54.

Cerussite (Carbon dioxide 16.4 per cent, lead oxide 83.6, or metallic lead 77.7 per cent).—This mineral occurs as a coating upon the sulphide and also at the Lansing mine in Allamakee county, in crystals lining small cavities in the galena. The ore from this mine is also frequently covered by a thin layer made up of numerous small, twin crystals of cerussite. Wherever the galena has been long exposed to the weather, as in the case of the float lead found in the soil, the carbonate supplies it with a white coating. In the formation of the cerussite, which is evidently a secondary mineral formed by the alteration of galena, the sulphide is first converted into the sulphate ($Pb\ SO_4$) and the latter, through the agency of

water holding bicarbonate of lime in solution, is transformed into the lead carbonate.

Smithsonite (Carbon oxide 35.19 per cent; zinc oxide 64.81, or metallic zinc, 52 per cent Sp. gr. 4.30-4.45).—The zinc ores found in Iowa are the carbonate, smithsonite ($Zn\ CO_3$) and the sulphide, sphalerite of blende ($Zn\ S$).

The carbonate, or "dry bone" as it is commonly called, is by far the most common in Dubuque mines. It occurs in a variety of forms which may be described respectively as cellular masses, botryoidal coatings, earthy masses and small bodies impregnating the rock. It often bears a close resemblance to the calcareous tufa found about so many springs in limestone regions. Sometimes it supplies a coating for galena crystals, or it entirely replaces them and forms pseudomorphs. Several interesting specimens were seen in which fossils had been entirely replaced by the carbonate. One of these was a slab of smithsonite on which were several large gastropods, their substance wholly gone and the place filled by zinc ore, the outline being perfectly preserved. The carbonate contains, on an average, from 30 to 40 per cent of zinc, though some specimens run as high as 49 per cent.

Sphalerite (Zinc 67 per cent, sulphur 33 per cent Sp. gr. 3.9-4.1).—The sulphide, the "black jack" of the miners, is much less abundant in the Iowa mines than the smithsonite. This is doubtless due to the transformation that has taken place, by which the former was changed over into the carbonate as will be explained later. The blende commonly occurs in compact layers or masses, and does not exhibit any crystal form. But crystals are by no means rare, being found in cavities in the limestones or in geodes. The sulphide is of a very dark, almost black, color and quite opaque.

The zinc silicate, or calamine, was not observed in any of the mines, though it probably exists in small quantities along with the smithsonite.

The change of the sulphide to the carbonate seems to have been very extensive, and the latter is probably all of secondary origin and derived from the blende. Several facts indicate that the latter has been the source of the carbonate.

(1) Specimens are very common in which the outside is dry bone, while the unaltered interior is composed of the sulphide. (2) In the lower levels and where water abounds the ore is the sphalerite. This is the universal rule and would seem to be owing to the fact that the lower deposits are not subjected to the atmospheric agencies at work nearer the surface. The chemical changes that have taken place in the zinc blende are probably as follows: The sulphide ($Zn\,S$) in the first place became, by oxidation, the sulphate ($Zn\,SO_4$), which is a very soluble compound; then through the agency of the alkaline and earthy carbonates in solution in the circulating waters, the zinc sulphate would be changed into the carbonate and redeposited in the crevices. Where the blende is under water it is little affected by oxidation and hence remains unaltered.

An excellent example of the alteration of zinc blende to dry bone is illustrated in figure 55 from a photograph of a specimen given to the survey by Dr. H. G. Knapp. The black jack is found here in pieces almost entirely surrounded by the carbonate, and the ribbed appearance of the latter is apparently due to the original cracks in the black jack, along which alteration began. Analyses of the two minerals from this specimen gave the following results:

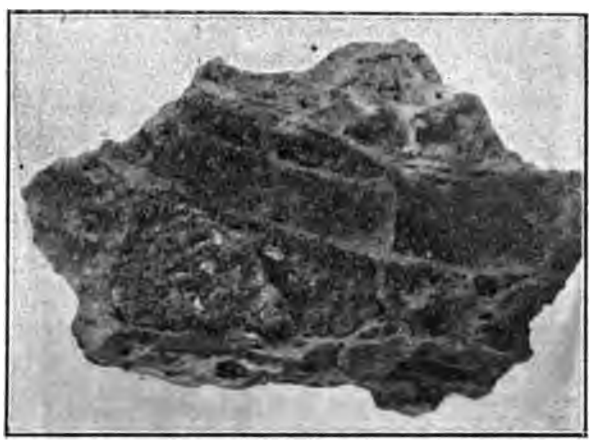


Fig. 55. Blende altering to dry bone. The reticulated dry bone shows surrounding the unweathered blende.

Black Jack............. Zn, 52 per cent; ZnO, 64.80 per cent
Dry bone..................................ZnO, 57.24 per cent*

A variety of different minerals occur in the same crevices along with the lead and zinc, and these deserve more than a passing notice, since they serve to throw light upon the origin of the two associated metals.

Copper.—Copper has been found at a number of points in the Upper Mississippi lead region, and was at one time mined and shipped from near Mineral Point, Wisconsin. It has never been found in extensive bodies, however, and has not previously been reported from Iowa. The copper found here occurs as stains of malachite and azurite on the carbonate zinc ores; the whole corresponding essentially to green calamine or aurichalcite. When pure this mineral carries 29.17 per cent oxide of copper, 44.71 per cent oxide of zinc; 16.19 per cent carbon dioxide, and 9.93 per cent of water. Specimens obtained from Messrs. Hird's mine near Center Grove, Iowa, showed 4.76 per cent metallic copper.

Pyrite and Marcasite (sp. gr. 4.95-5.10).—These are very common in the workings and are the "sulphur" of the miners. They have the same composition with a ratio of 46.7 of iron and 53.3 of sulphur, but crystallize in different systems; pyrite being isometric, and marcasite orthorhombic. The latter is commonly whiter than pyrite. They do not occur in well defined crystals so much as in crystalline aggregates of irregular form.

At the mine of the Dubuque Lead Mining company on the Ahern ground, however, the pyrite was found well crystallized. The limestone has here been much affected by dissolving agencies and is so filled with cavities that the rock has somewhat the appearance of a breccia cemented together by iron pyrites. Instead of the more common cube the mineral here occurs in perfect octahedrons sometimes modified by the faces of the cube. Penetration twins are also of frequent occurrence. The crystals vary in size from one-fourth to three-fourths of an inch. When exposed to the air these sulphides

*Equivalent to 88.33 per cent zinc carbonate.

readily oxidize and change over into limonite. This alteration is finely illustrated in a specimen from the Lansing lead mine. The interior is made up of marcasite while on the outside this has undergone a chemical change and a coating of limonite one-fourth of an inch thick has been formed. The same specimen is covered on one side by Galena and on the surface thus protected the marcasite has suffered but slight alteration, showing that the changes took place after the deposition of the Galena on the iron sulphide. Otherwise there would seem to be no reason why the limonite should not be of the same thickness on all sides.

Limonite. (Ocher Rust.)—This is a hydrated oxide of iron and is found in large quantities in the ore-bearing crevices where it was formed by the oxidation of the pyrite and marcasite. This alteration process has gone on so extensively that a large part of the original minerals has been changed into the iron oxide. It is usually impure and earthy, imparting to the clay and other crevice material a brown color.

Wad. (Manganese Dioxide.)—This mineral occurs as a black earth in several of the crevices at Dubuque; notably the black crevice. Manganese also forms a common accessory constituent in the Durango iron ore.

Calcite and Aragonite.—These are the most common of the associated minerals, occurring abundantly throughout the region. The following varieties were observed:

1. Well crystallized calcite; the "tiff" of the miners.
2. Fibrous variety or satin spar.
3. Lamellar, pearly white variety or argentine.

The two latter are closely associated and are found together in the same stalactites.

The crystallized calcite forms fine crystals and groups of crystals often of much beauty. A very common occurrence is the combination of the scalenohedron (R 3) with the rhombehedron (R) and the prism of the first order (P). But more complex combinations are found. Thus one specimen showed

the prism of the first order and three scalenohedrons, two positive (R 3 and ¼ R 3) and one negative, the latter beveling the acute angles of R 3.

Satin spar and argentine are associated in some crevices about five miles south of Dubuque (Tp. 88 N., R. III E., Secs. 16 and 17).

Some of these "spar caves" have been productive crevices from which large quantities of ore have been taken, while others are barren and filled to a greater or less extent with clay. The Galena limestone in this locality is cleft by a complex system of extensive fissures which form a labyrinth of underground passages, and in certain portions contain large deposits of calc spar lining the top, sides and bottom. The deposition of lime carbonate does not go on extensively where there is more than forty feet of limestone above the cap rock. One remarkable feature of these "caves" deserves more than a passing notice. The floor, which is formed of a layer of calcium carbonate 6–10 inches thick, is suspended in the top of the crevice. This is well shown in the accompanying figure (Fig. 56). The floor was evidently formed when the clay was at that height in the fissure and was deposited on top of this impervious material. Later the clay has settled, leaving the crevice open beneath the lime deposit; sometimes this settling amounts to as much as thirty or forty feet. The floor of the

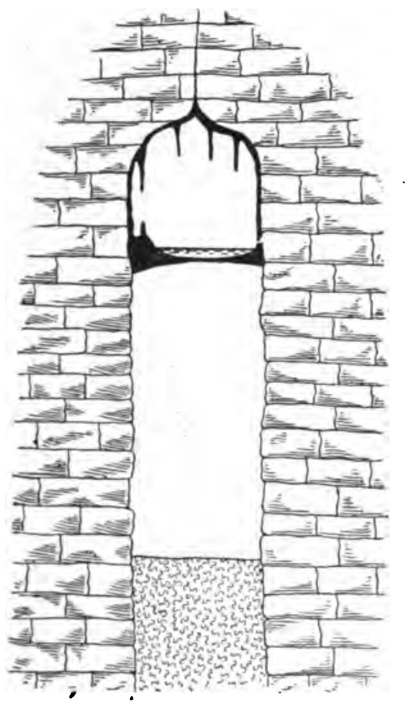


Fig. 56. Section through Kembling's spar cave suspended in top of crevice, stalactites and miniature lake.

cave thus forms a horizontal partition across the top of the crevice. It may be connected with the roof by several columns formed by the growing together of stalactites and stalagmites. On this floor is sometimes found a clear pool of water.

Fig. 57. Group of Stalactites from Kemling's cave, south of Dubuque.

The satin spar has a fibrous structure, silky luster and is colorless or white. It is made up of delicate acicular crystals of aragonite. The argentine (schieferspath) has a pearly luster and is composed of more or less undulating lamellæ of pure white color. The specimens found here agree well with the descriptions given by Dana and Tschermak. Several different forms of stalactites occur: (1) Those specimens which are pearly white on surface of fracture, with a silky lustre due to the radiating fibers that form a velvety surface of great beauty. This variety occurs in bunches or clusters of twisted and gnarled stem-like forms. (2) Stalactites proper; formed

of radiating fibers. In cross section these have a vitreous luster, and on the surface are (a) either covered with a fine white powder, and show no luster, or (b) the outer surface is formed of little rhombohedrons and has a silky luster. They are white or colorless; opaque or translucent.

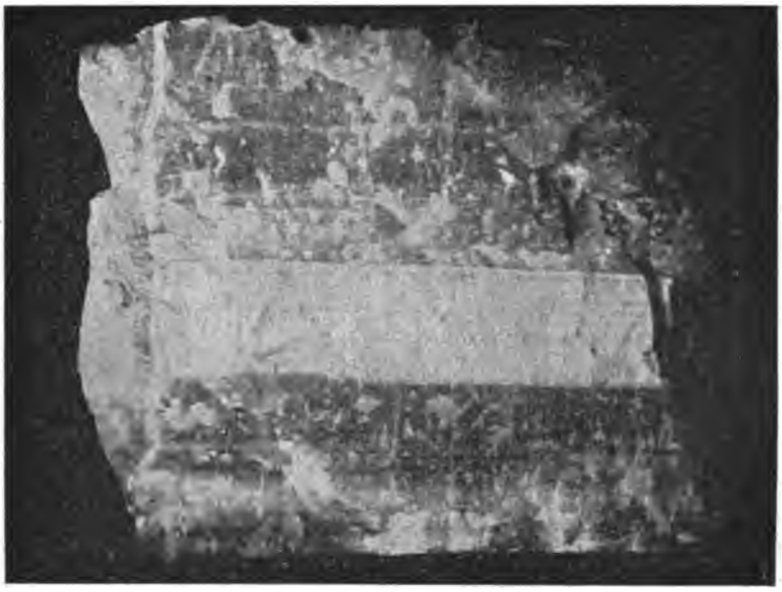


Fig. 58. Specimen showing band of pearly argentine in transparent calcite from floor of Kemling's cave, south of Dubuque.

Other stalactites have a concentric banded structure and possess several points of unusual interest. Beginning at the center they show (1) a crystalline or granular core, often displaying bright rhombohedral faces; (2) a thin band of clay, apparently wanting in some cases; (3) pearly white lamellar calcite (argentine); (4) a band of clay; (5) a fibrous aragonite; (6) an outer surface composed of little rhombodedrons.

Several features in the structure of these stalactites deserve special notice. There is every indication that the crystalline core was once fibrous, but this structure has mostly disappeared, especially in the larger specimens, and is replaced by the rhombohedral cleavage. In the smaller

forms the transition from the radiating fibrous variety to the crystalline aggregate of rhombohedrons can be traced. The long acicular crystals become less and less distinct, though traces remain visible after the rhombohedral form makes its appearance. Recrystallization has taken place and the molecules have rearranged themselves to conform to the interior structure of the rhombohedron; or, in other words, they are identical with the latter crystal form in all but external outline and this has been prevented from developing, showing itself only on cleavage faces. Another strong indication that this granular core was once fibrous is found in the fact that this latter structure is the common one in all these caves. The small forms all show the radiating fibers, but as they increase in size alteration has taken place.

Another point of interest relates to the band of pearly lamellar calcite occurring between the granular, crystalline core and the fibrous external layer. The white lamellæ form concentric rings in marked contrast to the radiating fibers associated with them. Occurring on both sides of the argentine in most cases if not in all, there is a thin band of clay. It is this that doubtless marks the suspension of deposition for a time, and when redeposition commenced the conditions were so changed that a different variety was formed.

The rhombohedrons forming the surface while the interior is fibrous, also deserve notice. They occur on the larger stalactites but not on the delicate branch-like forms. The exterior of the latter owes its silky luster to the innumerable fibers of which it is composed. They frequently form delicate cotton-like masses covering the outside of the satin spar.

On the majority of stalactites, however, the crystal aggregate of rhombohedrons occurs. They may have been deposited after the radiated interior was formed, but they seem to be due rather to the alteration or recrystallization of the fibrous mass, as in the case of the granular core. The conditions under which the fibers were formed have changed, and there

has been a corresponding change in the crystalline condition of the calcium carbonate.

The satin spar occurring in the large branch-like clusters is notable on account of its great beauty and rarity. As it

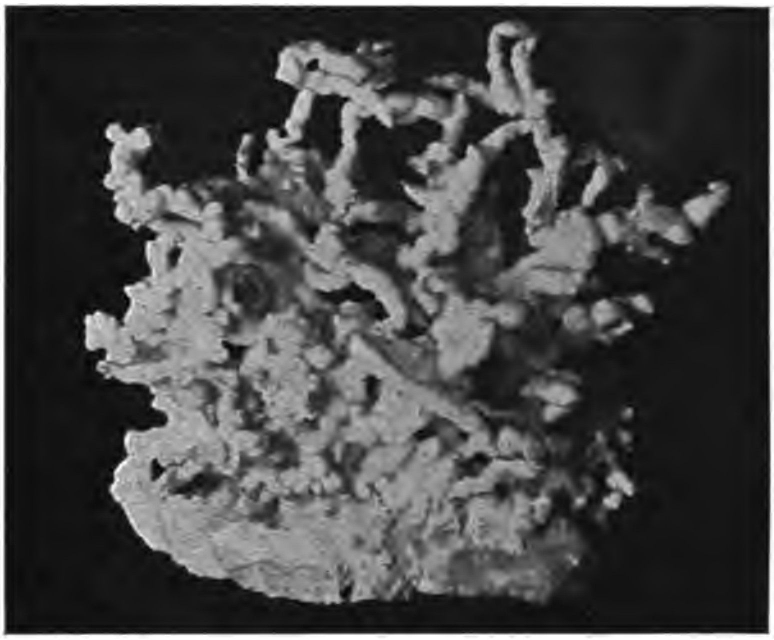


Fig. 59. Satin spar showing twisted stem-like forms. Linden's cave, south of Dubuque.

hangs suspended from the roofs of the caverns it resembles at a distance branching coral, but near at hand the twisted and gnarled stems with their beautiful silky luster bear no likeness to the polyp structures.

Gypsum.—This mineral is not of common occurrence in the region under view. It is, however, occasionally found in the crevices along with the ores. There is a very unusual occurrence of crystallized gypsum, or selenite, in the "spar caves." The specimens are found on the top of the clay forming the floor. The selenite occurs in very long acicular crystals. These needle-like forms are composed of two individuals, whose twinning plane is the orthopinacoid ($\infty P \bar{\infty}$), and are greatly elongated in the direction of the vertical axis. The

faces which appear are those of the clinopinacoid (∞ P $\overline{\infty}$) and unit prism (∞ P).

Two cleavages are well shown: (1) The most perfect is parallel to the clinopinacoid; (2) there is a second good cleavage parallel to the negative pyramid (- m P). The extent to which these twin crystals have been elongated is remarkable. One specimen had a length of 6½ inches, with a width of less than ¼ of one inch. Another was 5¼ inches long and extremely slender, being less than $\frac{1}{16}$ of an inch wide and perfectly transparent.

Dolomite (Sp. gr. 2.8–2.9).—Crystallized dolomite is not common, and when found usually lines the sides of small cavities in the limestone. Since the latter is highly magnesian, it might be expected that dolomite would more frequently occur, but its rarity is doubtless due to the greater solubility of the magnesian carbonate. On this account it would remain in solution while the lime carbonate was deposited.

Barite—Crystalline masses of heavy spar are occasionally found in pockets or druses in the Galena limestone. The Sunflower crevice has produced an exceptional amount of this mineral, though it is not uncommon throughout the region.

THE ORE BODIES.

The ores mined at Dubuque include Galena, or lead sulphide, to which locally the term mineral is commonly restricted, zinc carbonate usually called bone or dry bone, and zinc sulphide, which is known as jack. In Wisconsin the sulphide of iron is also mined, but while it occurs in the Iowa mines it has not as yet been marketed. To the miners is known as "sulphur." These ores occur in a considerable variety of forms ranging from simple vertical sheets to widely disseminated deposits. There seems to be no close association of particular ores with a particular form of ore body, and only a general association of a particular ore or particular form of ore body with particular stratigraphic horizons. Such associations as have been noted will be described later. Considering first the diverse

forms of ore bodies it is seen that they may be grouped into *a* vertical sheets, *b* horizontal sheets or "flats," *c* "pitches," *d* disseminated bodies, and *e* cave deposits.

Vertical sheets.—The simplest form of ore body occurring in the region is the familiar vertical sheet similar in all essential particulars of form to the vein deposits of other regions.

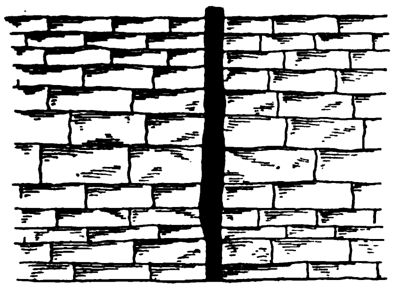


Fig. 60. Vertical sheet of galena in McPoland and Basler mine.

A vertical sheet, in this case carrying lead ore, is illustrated in figure 60. This sheet was sketched in the McPoland and Basler mine in West Dubuque in 1899, but similar sheets have been followed in the Avenue Top and a large number of other well known mines. The simple sheet of mineral, here one-half to three-quarters of an inch thick, lies between undisturbed dolomitic walls. These walls have weathered to a loose dolomitic sand for a distance of three to eleven inches on either side of the sheet. There are no selvage bands, no signs of faulting nor any crustification* such as is usual in the deep seated veins of the west. The genesis of the deposit is simple and obvious. The narrow crack in the rock became filled, by means later discussed, with galena, and since that occurred the dolomite has weathered as shown. If the circulation of underground waters had removed a portion of the dolomitic sands, the crevice would have been found partly open and partly filled with loose sand mixed with small chunks of mineral. This is a very common form of occurrence in the region.

As in all mineral veins these vary in richness and character from point to point. The sheet of mineral pinches out in all directions, thickens and thins, and when its dimensions are considerable the lead plays out and the zinc takes its place on the same level, or at different levels on the same

*Posepney; Trans. Amer. Inst. Min. Eng., Vol. XXIII, p. 207.

vein. In general, near Dubuque vertical sheets are more common in the north-south crevices. The east-west crevices, opening out toward the main drainage lines, and hence offering a freer course for underground waters, are usually broader, and if the mineral ever occurred in them in vertical sheets this form is now usually destroyed. The north-south crevices, at Dubuque, are rarely important producers, but often lead to important deposits where they intersect with east-west crevices.

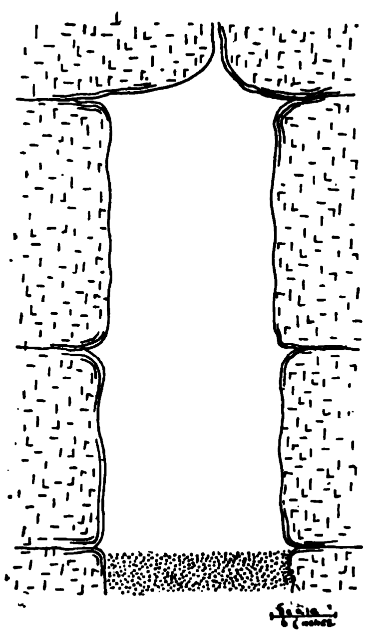


Fig. 61 Sketch of a quartering crevice in Leven's mine. Drawn to scale.

Flats.—This form of deposit has been extensively worked in Wisconsin, but has not yet been developed in any large way west of the river. In the flat the ore has the position of a blanket vein and runs off in a horizontal sheet parallel to the bedding. It is a most valuable form of deposit, as it allows the easy working of a large amount of ore. The flats so far developed in the region have not, usually, any great thickness, three to eighteen inches covering all but a few of the beds. In general the flats are found best developed in the lower portions of the Galena formation, and they show zinc blende, rather than lead or dry bone. The latter minerals occasionally tend to run off into flats in the upper levels, but no extensive flats of this kind have yet been found, nor are they to be expected. The flats

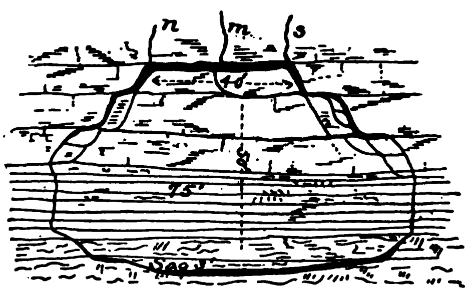


Fig. 62. Sketch showing relations of flats and pitches after Chamberlin.

are developed along stratification planes, and seem to indicate that at certain horizons the mineral-bearing solutions found it easy to wander out laterally and form sheet deposits. They are not believed to represent here original interbedded deposits.

Pitches.—This form of deposit was discriminated by Chamberlin,* who very correctly considered the flats and pitches as simply different phases of one form. There is, however, some practical convenience in studying them separately. The relations of the flats and pitches are shown in figure 62 redrawn from Chamberlin's figure of the Roberts mine at Linden. It represents the usual development of the form except in the presence of three vertical crevices above instead of one. The pitches are usually relatively short and represent merely the arms by which vertical sheets are connected with flats. The ore body does not change direction with a simple right angle but by a series of steps as shown in the figure. A good example of a pitch in the Dubuque mines is the Alpine ore body. Pitches, with the flats, are usually found low in the Galena formation. They represent the normal verging off of a vertical fracture as it reaches a series of beds of different resistance, and Chamberlin has shown that pitches are usually developed in synclines. While occasionally a pitch is found showing a single arm, the double arrangement is more common and if a vertical east-west sheet be found pitching to the north, it may usually be assumed that there is a corresponding pitch of ore on the other side to the south.

Disseminated ore bodies.—So far as present development has gone, no large bodies of disseminated ore, such as are worked in southeastern Missouri, have been found. Nevertheless the wall rocks in many of the crevices show a certain amount of disseminated ore. In the Spring street or Fourteenth street, the various levels show a large amount of ore carrying dry bone to as much as 20 per cent. In the Bush, Alpine, and

*Geol. Wisconsin, Vol. IV, pp. 439-480.

Avenue Top there are large bodies of ore mixed with rock. In the mine formerly worked on the Ahern ground, the lead was found in small pieces scattered through the dolomite and could only be removed by jigging. The recently developed black jack deposits in the Pike's Peak country are really dis-

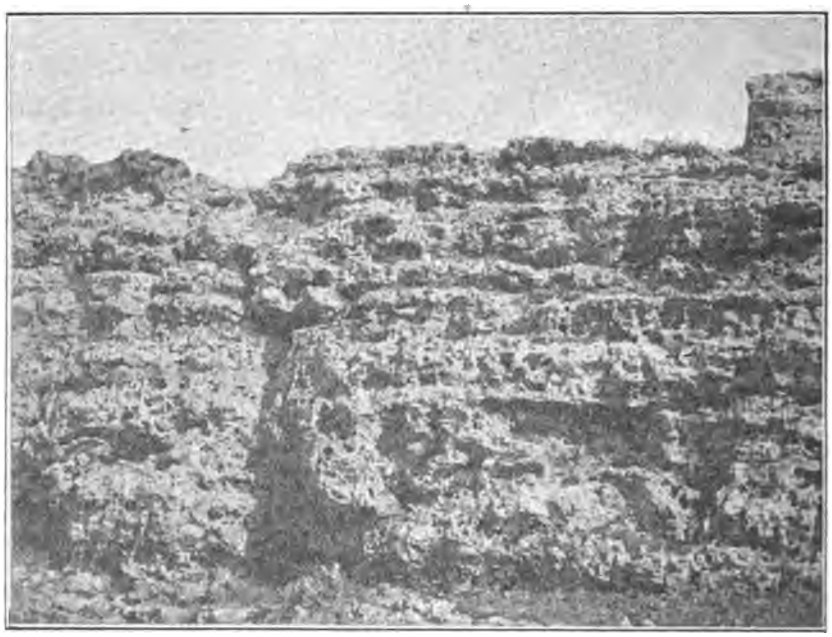


Fig. 63. Weathered surface of Galena limestone near Rockdale.

seminated. Wherever, in fact, the rock has been broken or rendered porous by solution there is a probability of disseminated deposits. The disseminated ores so far uncovered, aside from cave deposits, seem to represent impregnation of rocks rendered porous by solution rather than by fracture. In figure 63 the character of a weathered face of dolomite is excellently shown. The rounded cavities are evidently the work of solution and correspond to those described by Bell.* To a certain extent similar faces occur along the underground crevices, and the underground waters have penetrated

* Bul. Geol. Soc. Amer., Vol. VI, pp. 297-304.

the side walls so that the rock is similarly open for some distance from the crevice, but of course to a decreasing degree. In the case of the disseminated ores these openings have been later filled by the ores. In instances small glode like cavities lined with ore are found some distance from the crevice walls in apparently barren rock. The absence, up to the present time, of milling facilities has made it impracticable to work anything except the richest and cleanest ores. As a result disseminated ore bodies have not been looked for. The prospects of locating and mining these is one of the most hopeful lines of development in the district. In Missouri ores carrying 10 per cent jack or 5 per cent of Galena, and in times of high prices those carrying even smaller percentages, are mined and milled at a profit; and it can hardly be doubted that ores of this grade are to be found at Dubuque in considerable quantity.

Cave deposits.—The cave deposit is the one in which most of the larger and richer bodies of ore so far mined in the region have been found. In the early days of mining it was the dream of every miner to "break through" and find a cave which in his fancy was always lined with great crystals of glittering galena. Enough caves of this character have been found to lend color to all such dreams, for the Stewart's cave, Dubuque's cave, Leven's cave and others were all large producers. Some of them will be more particularly described later.

The caves are evidently but large developments of the crevices and openings. They are usually formed when several crevices come near together. The ore occurring in them is either attached to the walls, sometimes lining them as calcite or quartz so commonly lines geodes, or mixed with the loose dirt and rock in the bottom. In either case a large amount of ore is obtained with very little effort. The caves are occasionally of notable extent. In west Dubuque there is an area so cut up by open labyrinthine passages below ground and so full of water that it is known as the McPoland

pond. On one occasion a small skiff was taken down a shaft and used in exploring this ground. It is believed that if the water could be drawn off large bodies of ore would be uncovered.

The caves are usually rich in mineral for the obvious reason that within them is accumulated all the ore originally in all the rock cut out to form them. They are, too, the meeting place of waters flowing along many crevices, so that precipitation is apt to be unusually active. They expose a large wall surface to the action of the forces which produce lateral segregation and accordingly nests of ore or even sheets are commonly found along their roofs or sides.

Chimneys, which are common along the crevices and which usually yield important amounts of ore, are incipient caves. All gradations can be found between the narrow vertical ore shoot which forms the typical chimney, and the great open cave. Usually the chimneys are full or partially full of broken rock which has tumbled in from the sides, and the ore is found cementing these pieces of rock. Dry bone is found largely in chimneys since it is a secondary deposit.

FORMATION OF CREVICES.

The earliest ores worked at Dubuque were the vertical sheets, and from their likeness to veins as mined in other regions they were called veins. Later, as the local peculiarities of the region became better understood, they came to be called crevices. Whitney invented for them the name of gash veins.* He defined the class as intermediate between segregated and true veins. Like the latter they occupy pre-existing fissures, but they are of limited extent and are not connected with any extensive earth movement. They are usually confined to one formation, being cut off below at any change in either the mineralogical or lithological character of the rocks. Whitney was inclined to consider them as genetically distinct from true fissure veins and states that the "origin of

*Metallic Wealth of the United States, pp. 48-49. 1854.

this class of fissures, must in all probability, be referred to the contraction of the rock caused by shrinkage, either while gradually undergoing consolidation, or from the effect of long exposure to somewhat elevated temperature." It now seems probable, however, that the difference between gash and fissure veins is one of degree of development rather than of genesis. The Dubuque veins were Whitney's type of gash veins and even a slight study shows that it is out of the question to assume that the rocks here have been subjected to "elevated temperature." A study of the crevices also convinces one that they cannot be referred to shrinkage as that term is now applied to rocks. Shrinkage could properly be assumed to be the origin of such fissures as are commonly known as mud cracks, but is not to be lightly assumed in connection with any other form of cracks in sedimentary rocks. Mud cracks are most frequently formed in unconsolidated rocks and have rarely any general relation to each other over wide areas.

The crevices at Dubuque were evidently formed after the rock was dolomitized and had become, essentially, as firm as now. The great shrinkage, 12 per cent, which took place in the change of the limestone to dolomite does not express itself in these cracks apparently, but in the large number of small cavities which distinguish even hand specimens of the Galena phase from that of the Trenton.

The crevices at Dubuque bear definite relationships to each other. The major crevices run very nearly east-west. They are crossed by a second set at almost exactly right angles, while a third set of minor crevices come in at nearly 45°. It is not so much that the cracks are at right angles, which is significant, but the major crevices are closely parallel to a series of low, broad folds which cross the region. The most pronounced of these folds is one already noted as having its crest cut by the river at Eagle Point.

When Whitney worked in the region joints, fissures and folds were considered to be radically different sorts of things.

They are now believed to be but diverse results of one general phenomenon—deformation. The parallelism between the major crevices of the region and the most pronounced folds strongly supports this theory. All the phenomena indicate that at some time later than the consolidation of the beds the strata were subjected to a certain amount of strain, and in their effort to accommodate themselves to this strain they were in part slightly folded and in part were cracked. When a rock or body of rock is subjected to stress this tends to relieve itself by a change of form or of dimensions. All rocks are under more or less strain, and even relatively strong rocks, if merely unequally supported,* tend to accommodate themselves to the various stresses to which they are subjected. If a rock be homogeneous it acts as a unit, but if there be differences in density or strength the various stresses are deflected from point to point. If the rock be soft and plastic, as is true of much the larger portion of the Maquoketa shale, the strain is accommodated by flow rather than fracture; that is, the individual particles of the rock move rather than great masses of rock itself. If the rock be thin bedded, and if, furthermore, its character change from bed to bed, as is true of the Trenton limestone, particularly when interbedded with shale, the stresses act on smaller blocks of rock, and deformation takes the form of numerous small fractures. It is very common to find the Trenton broken up into a large number of small blocks rather than in solid ledges. When, however, the rock is homogeneous, firm and of low elasticity, stresses are resisted for a longer time, and are ultimately relieved by great cracks extending, perhaps, for miles. The same amount of deformation may thus be accommodated in different ways in the rocks of the same section. Van Hise has shown that one rock may be so squeezed as actually to flow under pressure, while another, under the same conditions, is merely broken.†

*Iowa Geol. Surv., Vol. VIII, pp. 378-379.

†Van Hise: Sixteenth Ann. Rept. U. S. Geol. Surv., pt. I, p. 601.

The Galena limestone is a very massive formation. It is thick bedded, and the bedding planes themselves are not marked by any notable amount of shale or other foreign matter. The rock is of low elasticity. The formation is of considerable extent and of some thickness. This formation has been subjected to certain stresses, and these stresses have been relieved by the cracking of the rock. There seems to have been very little displacement, either vertical or horizontal, though there are well authenticated cases of a certain amount of faulting,‡ and nothing is more common in the mines than tipped blocks. The latter are, however, due to secondary settling and can be clearly shown, in most cases at least, to be due to the washing out of material below. They are local phenomena of no general significance, and are more common in the larger crevices.

The instances of horizontal faulting which Jenny mentions* seem to be merely the common phenomena of one crack shifting its course when crossing another. Stress, for example, develops the cracks *a–b* (figure 64) but when this crosses *c–d* the rock proves to be a little stronger and so the stress between *c–d* and *e–f* is relieved along the line *g–h*, parallel to the original direction but a short distance away. After crossing *e–f* the stress may be relieved along the original course forming the crack *i–j* or it may take any near parallel course, *k–l* or *m–n* for example. The latter will be much more likely to happen if the force which produces the crossing crack be later in time and come at a slight angle to the original force. In general the two sets of cracks

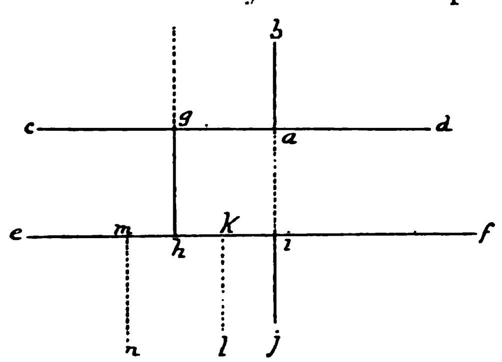


Fig. 64. Diagram illustrating apparent horizontal faulting.

‡Blake: Trans. Amer. Inst. Min. Eng., Vol. XXII, pp. 621-634.

*Trans. Amer. Inst. Ming. Eng., Vol. XXII, p. 206.

are of practically contemporaneous origin, as a stress acting through a homogeneous body tends to relieve itself by two planes at right angles. It is not necessary to assume a horizontal faulting to explain such phenomena as are here described, and in fact such an explanation requires much better evidence than has yet been found to support it. The phenomena are simply more striking instances of a common condition. In the Dubuque region, as elsewhere, the main crevices or cracks, while following the same general course, are not strictly parallel. They cross at low angles and at these crossings one or the other of the two crevices is apt to be slightly deflected. For example, *c-d* (figure 65) in crossing *a–b* is deflected slightly from the straight line *d–f*. Yet there has been no faulting. The rock walls on either side of *a–b* correspond directly. The stress tending to produce the fracture *c–d* has merely been relieved for a portion of its course by the nearly parallel *a–b*. Instances of such change in the direction of crevices are common and will be illustrated in describing the mines.

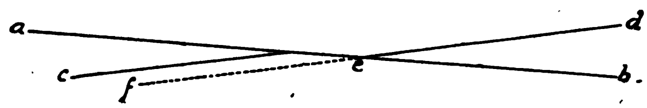


Fig. 65. Diagram illustrating relief of stress along a nearly parallel pre-existing crevice.

In the study of deformation, faulting and kindred topics, it is important to keep in mind that the appearance of great deformations is sometimes produced in rocks which have really been very little disturbed. An excellent example of this occurs near Specht Ferry and is illustrated in figure 66. Apparently the figure illustrates a shearing plane in horizontal rocks and when first seen was thought to mean a considerable amount of deformation. Close study has shown, however, that the lines of stratification pass directly across the shearing plane without displacement. There has been no arrangement of particles due to intense lateral pressure, no repeated faulting along closely parallel planes, nor any of the phenomena for which shearing usually stands. It is

merely an instance of a large number of closely parallel vertical cracks, and there has been no displacement. Such an exposure, if found in a region of disturbed rocks, would probably be used as evidence of great dynamic movements, but in this situation it can not be so regarded.

Fig. 66. Shearing in Galena limestone near Specht Ferry.

The ore bearing rocks of the Dubuque region are essentially undisturbed. The low folds found in the region are simply the expression of such slight earth movements as have probably taken place in all regions. The exceptional development of the crevices is due to the inelastic and homogeneous character of the rock which has allowed the formation of single crevices, or bunches of closely parallel crevices, such

as the Timber range, which is known to extend in a fairly constant direction for a distance of five miles and more.

As already stated the major crevices have an essentially east-west direction. They are crossed by a second set at right angles, and a third set is occasionally encountered crossing at 45°. The crevices of any one set are not exactly parallel and may cross each other at low angles. The ore bodies are more commonly found at crevice intersections, so that the tracing of the crevices is quite important. Most of the large crevices have been worked at various times, and can be followed across the country by a line of old shafts. Beyond such a line they are usually located by taking the bearing of the crevice line and projecting it. Many of the crevices have been opened up at intervals over a length of one or two miles, and several are known for more than five miles of their course.

ENLARGEMENT OF THE CREVICES.

If the ore bodies simply filled in the original crevices, the amount of mineral would be quite inconsiderable. In instances where a simple sheet of undisturbed mineral occurs, the sheet is usually quite thin. A half or three-quarters of an inch is common, and in most of such crevices the ore body is not more than a few inches in thickness. The larger number of the mines, however, work much larger ore bodies, and the crevices, particularly at those horizons at which "openings" occur, are normally much wider. In a large number of mines the openings are from eighteen inches to four feet in width. Openings ten and twelve feet wide are not uncommon, and the Levens and other famous ranges are in places open from from thirty to forty feet in width. The Stewarts cave, more particularly described later, has a width of seventy-two feet. When, however, a crevice exceeds ten feet in width it is usually due to the coming together of nearly parallel crevices.

Manifestly there has been some agency at work cutting out and broadening the original cracks in the rock, which may

fairly be assumed to have been at first quite narrow. A little study shows that this widening of the crevices has quite certainly been done by the circulation of underground water.

When rain falls upon the earth a portion of it runs off over the surface, a portion is evaporated by the sun's heat, and a portion sinks down through the soil and into the rock. This latter portion reappears at some lower point as a spring, or comes out in a line of seepage on some hillside. All rocks are more or less porous, and water finds its way through all of them, but with very greatly varying facility. Some rocks are so nearly impervious that water tends to collect along the upper surface and run off over, rather than through them. In this immediate region, for example, very little water passes through the shale, which overlies the Galena limestone, and wells usually obtain a lasting supply at the base of the drift and on top of the so called slate. Other rocks, such as the Saint Peter sandstone, are so open and porous that water passes through them readily, so much so that the whole of the rock is usually full of water. When the underground waters reach a crevice or crack they tend to follow along it just as the surface waters follow along valleys. Indeed, back of a spring there is a ramifying series of lines of drainage in the rocks corresponding in many particulars to the surface streams below the various springs. As the waters flow through the cracks they cut away the rock on either side. The action here is, however, quite different from that of surface waters. The latter do most of their cutting mechanically; that is, the bits of rock and sand carried by the stream rub and cut away the rock on either side and on the stream bottom. Underground waters rarely move with sufficient velocity to give them much erosive power, and their action is mainly chemical.

Surface waters are charged with certain proportions of various salts and acids, notably with carbonic acid gas. In the presence of this gas limestone is soluble in water to the extent of about one to 1,000 parts. In the course of their journey through the rocks the waters become charged with

various other solvents and thus exert an important chemical effect. They dissolve and carry away the rocks forming the sides of the crevices, and even eat away so much of the rock that great caves are formed. Rice's and Ball's caves south of Dubuque have long been locally famous for their extent and the beauty of the stalactites found in them. They have been described by Leonard* in some detail, but it is merely imporant to observe here that the formation of the crevices was due to the same agencies working in the same way as those that produced the caves everywhere common in limestone countries. In connection with the question of the origin of the ores it will be necessary to consider more in detail the character and modes of action of underground waters.

The Openings.—In sinking on one of the crevices or vertical seams it is customary to find that the vein opens out at intervals in large cavities in which the bulk of the ore is normally found. These openings occur quite constantly at certain definite stratigraphic planes listed below as ore horizons. It is not unusual, however, to find chimneys extending from one horizon nearly, if not quite to the one above. On the other hand a broad and well defined opening may be abruptly closed in by a flat "cap rock" cut by a mere line marking the course of the crevice (figure 67). Below the openings the crevices close up again, occasionally abruptly but more usually by gradual narrowing in the walls. The chimneys, some of which are illustrated in the sketches of the mines, are commonly located where the master crevice is crossed by a minor one. They seem to develop from below upward. The opening below being clear, a portion of the roof caves in. This material being dissolved and carried away, more drops, and so the process continues until the chimney has eaten its way up to some resistant

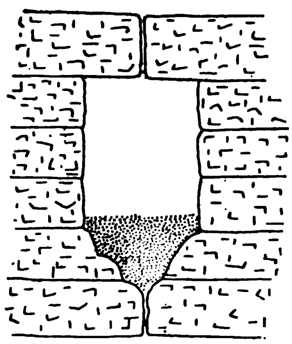


Fig. 67. An opening showing crevice cutting cap rock above and an accumulation of dolomitic sands below.

*Lead and Zinc Deposits of Iowa, Iowa Geol. Surv., Vol. VI, pp. 30-35.

stratum or to the first opening above. The chimneys, as well as the crevices, may be full, or partially full, of great blocks of fallen rock, of brecciated dolomite, or of dolomitic sands. Occasionally these sands have evidently been moved by running water and redeposited just as above ground. In the Kane Brothers mine near Key West cross-bedded sands were seen, and the upper opening, which should normally be found forty feet below the slate, had been cut up so high that the basal portion of the Maquoketa was exposed in the roof. The actual open space was here some feet above the normal level of the first "opening," and the space between was filled with soft dolomitic sands.

The reason for the expansion of the crevices at definite horizons is doubtless to be found in the greater solubility of the rock of the particular layers occurring at these horizons. Analyses made, however, with a view to determining this fail to show anything conclusive. There seems to be no greater difference for example between the character of the rock of the first opening (analysis 43) and that of the upper thin beds (analysis 41), than between other portions of the Galena. An alternative hypothesis is that the various openings indicate definite stages of level of the underground drainage much as terraces mark similar stages along surface streams. If this were true, however, it would be expected that as one passed back from the main drainage lines the openings would forsake the particular beds usually affected and rise as would the grade of a surface stream. While there are some facts which suggest such an interpretation, it cannot in fairness be said that much of the evidence supports it. The openings follow particular beds rather closely, and the movement of underground water is too capricious to be with any certainty referred to definite grade levels. Solution is so much more important than erosion that there seems to be but little opportunity for the development of an underground base level, if such a term may be used.

In any consideration of possible lower ore bodies it is important to know whether the crevices and openings may be expected to occur in the lower portion of the Galena, the part now below water level. There is no reason to doubt that the crevices extended down to the Trenton if not to the St. Peter. As already suggested the Trenton has been cut up more frequently by a number of small crevices rather than by a few big ones. Nevertheless direct observation shows that at Eagle Point and elsewhere the lower portion of the Galena and the Trenton are cut by crevices in all particulars fitted to serve as ore carriers.

The question of possible lower openings depends manifestly on the former level of drainage. Large cavities are only cut in the rock where the latter stands high enough above the surrounding drainage level to permit relatively free underground circulation. Below such a level the rocks are full of water which moves but slowly and in obedience to the principles controlling artesian wells. There is no reason to believe that such waters exert any important influence in the matter of cutting out or eating out large openings, such as are common in this region. Their action in ore deposition is rather metasomatic. As the water takes up into solution a portion of the limestone or other country rock it deposits a corresponding portion of ore. This process leads naturally to the formation of ill defined disseminated ore bodies. So far such ore bodies have not proven to be important in the Dubuque region. The ore bodies now mined are found in cavities such as could only be formed, in any notable degree at least, in rocks above the general water level. The question then becomes one as to whether the general water level ever stood lower than at present.

Chamberlin, Salisbury,* and Leverett,† who have studied this question in connection with the past history of the Mississippi, believe that the present river bed has been filled in to a notable degree; probably as much as 100 to 150

*Chamberlin and Salisbury: Sixth Ann. Rept. U. S. Geol. Surv., p. 223.
†Leverett: Jour. Geol., Vol. III, pp. 746-749.

feet. At Dubuque Leverett places bed rock at 453 feet above tide, or 132 feet below low water level. An inspection of the topographic map shows that the Couler valley and the valleys of the Little Maquoketa and Catfish creek, have obviously been filled near their mouths. At the Julien House, elevation 615 A. T., the depth to rock was shown by the artesian well to be 210 feet.*

Leverett's observations are confirmed by all that is known of the Mississippi, and while the latter may not always have been the master stream of the region, it certainly has been for a very long period. As the master stream it has determined the grade level of the tributary flows, both above and below ground. Since at one time it flowed at a level of 100 feet or so below its present surface, and apparently maintained itself at this level for a considerable period, there is little reason to doubt that the circulation of water through the lower portions of the Galena has been active enough to lead to the formation of openings, though they would naturally not be expected to be either so numerous nor so large as in the upper, more exposed, portion of the formation.

Ore horizons.—Taking up in detail the various layers which make up the Galena, there are certain ones which attract especial attention, since they are characteristic ore horizons. It is not that ore is always found at these horizons or that it is never found elsewhere, but the great bulk of the ore so far mined is found along these horizons or near them. These openings, from the top down are as follows:

1. *Top opening.*—Commonly worked in West Dubuque. May be seen in the quarries on Eighth street and is represented in figure 47. This occurs below the thin beds or quarry rock and is normally about forty feet below the base of the Maquoketa and about twenty feet above the Receptaculites horizon elsewhere noted. As is true of all of the openings, this one may chimney up a number of feet, in this case being occasionally

*Norton: Iowa Geol. Surv., Vol. VI, p. 213.

open clear to the slate. The horizon given is the one at which the opening is most commonly found.

2. *Middle or second opening.*—Occurs in heavy bedded dolomite forty-three feet below the top opening.

3. *Third opening.*—This is the lowest one worked in West Dubuque and carries jack in the Alpine, Avenue Top, Bush, Fourteenth street and other shafts of the region. It is normally twenty-six feet below the second opening, though the two may be chimneyed together.

4. *Upper Flint opening or jack opening.*—Found approximately twenty feet below the cap of the third opening. Not worked in West Dubuque though known to carry ore in certain mines. Open at Durango and in the Pike's Peak region. The upper flint and the third opening often run together.

5. *Lower Flint opening.*—Separated from the upper flint opening by about twenty feet of fine dolomite. This horizon is very productive in the region adjacent to Shullsburg, Wisconsin, where it is often known as the sixty-five-foot opening, that being its approximate distance above the base of the Galena. At Eagle Point the two beds of flint are quite distinct. Elsewhere in Dubuque county they seem to merge so that it is not certain that numbers 4 and 5 will prove to be distinct horizons here.

6. *Pipe clay opening.*—At the top of the Trenton limestone at Eagle Point there is a bed of green shale which seems to mark a definite stratigraphic horizon. In Wisconsin this has proven a good ore horizon, though in Iowa there is as yet no evidence on this point, the shale never having been prospected.

It is this opening which has yielded east of the river the largest amount of ore, and which so frequently shows well developed flats. Blake speaks of it as "at the base of the ore deposits,"* and over much of the region this will doubtless be found to hold true. Ore has, however, been found below it, and Whitney speaks of the "Glass Rock" opening

* Trans. Amer. Inst. Ming. Eng, Vol. XXII, p. 63.

and the "Lower Pipe clay" opening, both of which mark horizons below this. The former occurs at the juncture of the blue limestone and the lower buff beds, and the latter is at the horizon of the shales found between the lower buff beds and the Saint Peter sandstone. No great hopes that these horizons will prove widely productive can, however, be fairly held out.

DESCRIPTION OF INDIVIDUAL CREVICES.

Before taking up the question of the origin of the ores and certain practical matters connected with their mining and milling, it seems best to give brief descriptions of the leading workings. Since many individual shafts are located at different points along the same crevice, it is convenient to take up the subject by crevices or ranges, the latter term in this region being understood to cover a series of closely parallel crevices acting essentially as a unit. Many of these crevices are not now being worked, and of others it has only been possible to visit a portion of their known extent. In a few instances mines have been open during a portion of the time devoted to this survey and still it has proven impracticable to visit them. Not all of the crevices have been definitely located, and upon the accompanying map (Plate No. 7) only the leading ones are indicated. For purposes of comparison Whitney's map of 1858 is reproduced. (Plate No. 8.) Certain of the descriptions and figures of the older mines are also from this report.

Much the larger number of the mines so far worked within Dubuque county are located within the immediate vicinity of Dubuque, and many of them are within the city limits. Some of the most important are in the thickly settled portion of the city, and are reached easily by street cars. Dubuque township includes nearly all the mining territory. A certain amount of ore was formerly found near Peru, in the township of that name, and mines have been worked in Jefferson township, around Sherrill Mound and elsewhere. Table Mound

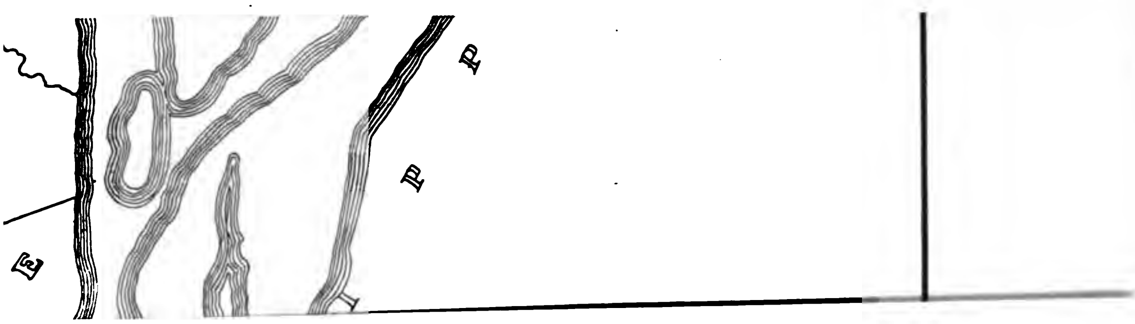
township, notably near Key West and Rockdale, has yielded some ore, and the Kane Bros. mine near Key West is now yielding lead. In Mosalem township some ore has been found, though no important mines have been opened. It is believed that all the area marked on the accompanying geological map as covered by Maquoketa and Galena, that is practically all the country between the Niagara bluffs and the river, is liable to be found ore-bearing where the local conditions are favorable. Practically the largest bodies of ore have been found in the crevices south of, and parallel to, the low anticline cut by the river at Eagle Point, and in the Timber Range which parallels this anticline to the north.

The Timber Range is one of the best known in Dubuque county. It has been worked for many years, and may be traced from its intersection with the Couler valley into the hills back of Durango. The early workings were for lead, and the most extensive mining was at the old Ewing diggings. These mines were visited by Whitney in 1856, and his description is in part given below:*

The diggings on the Little Maquoketa river, near Durango, were formerly very productive, having given employment to more than one hundred and fifty men at one time: they are now almost entirely abandoned, and in 1856, when this district was last visited by us, only a few persons were engaged in washing over the old rubbish. There is a very remarkable range or series of crevices running N. 80° W., S. 80° E. for a distance of between one and two miles along the middle fork of the Little Maquoketa: in this range, the indications of heavy workings may be seen on almost all of the points of the bluffs coming down to the river on the south side. On the Sw. ¼ Sec. 31, Tp. 90, R. II E. at Ewing's diggings, the crêvice is said to have been thirty feet wide, and to have produced large quantities of lead. This locality will be noticed farther on, under the head of zinc.

Within the limits of Iowa the only ore of zinc which we have noticed in any considerable quantity, was the carbonate, associated with the silicate, at Ewing's diggings on the Little Maquoketa, a few miles northwest of Dubuque. Although the interior of the excavations was not accessible, it was evident from the inspection of the rubbish lying on the surface, that a considerable quantity of these ores, called by the miners "dry bone," had been raised in connection with the Galena. Much of the ore at this locality has a cellular structure and an earthy texture, and portions of this variety are covered with stalactitic and botryoidal incrustations. The chemical examination of some of the cellular masses showed them to consist of mixtures of the hydrous silicate of zinc, or electric calamine, with the carbonate, or smithsonite, and more or less argillaceous matter. The first mentioned of these ores contains 67.4 per cent of the oxide of zinc; the other,

*Geology of Iowa (Hall), Vol. I, pp. 457-470.



64.8 of the same. Analyses of the incrustation and of the stalactitic masses proved them to consist of nearly pure carbonate of zinc, giving the following results:

	PER CENT.
Insoluble in acid, silica, chiefly	.14
Oxide of iron and alumina	2.96
Oxide of zinc (49.67 zinc)	61.89
Carbonic acid, water and loss	35.01
Total	100 00

A specimen of the stalactitic variety gave:

	PER CENT.
Insoluble silica and clay	2.56
Oxide of iron and alumina	.66
Oxide of zinc (49.38 zinc)	61.53
Carbonic acid	32.03
Water and loss	3.22
Total	100.00

In 1894-96 the Durango mines were extensively worked for dry bone by Mr. E. T. Goldthorpe. Dr. Leonard visited the works at that time and has given the following description:*

The Timber Range, or old "Ewing Diggings" at Durango, five miles northwest of Dubuque (Tp. 90 N., R. I E., Sec. 36, Se. ¼.) was once famous for its Galena. The range has a width of 100 feet and is formed by three main crevices

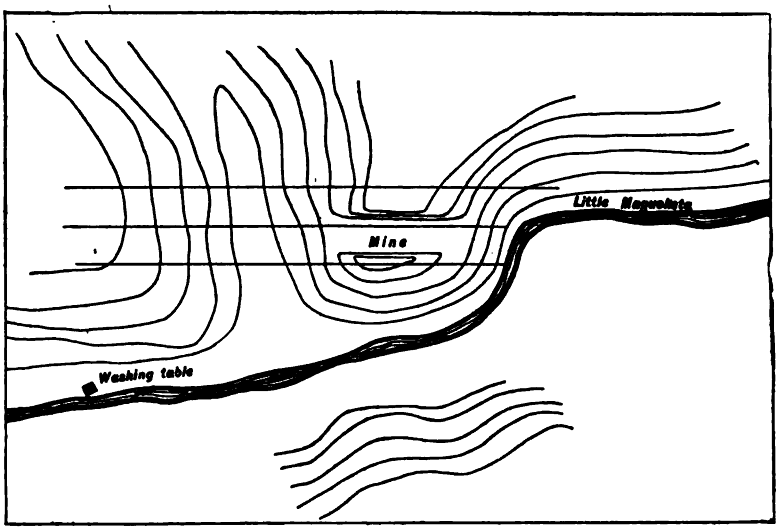


Fig. 68. Sketch showing location of Durango zinc mine in hill above the Little Maquoketa. The crevices represented.

with a general direction S. 80° E. The openings occur ninety feet below the crown of the hill, and where they are enlarged the three fissures unite in caverns of immense size.

*Iowa Geol. Surv., Vol. VI, pp. 45-47.

In these openings the lead occurred, and above them, extending to the surface, the hill is filled with zinc carbonate. The zinc is known to extend also below the level of the lead. The mine is worked by means of an open cut extending through the hill with a width of forty feet and a depth of about eighty feet. The crevices are more or less open up to the surface. Several can be seen in the face of the cut, and in them the ore is most abundant, though this is also found mixed all through the fractured limestone. The strata have been subjected to more or less strain, possibly owing to the large caves below, and are broken into fragments. The carbonate is found coating these pieces and filling the spaces between, occurring also, as stated, in the open crevices. The latter,

Fig. 69. Open cut at Durango zinc mine.

where they appear in the cut, have a width of from one to two feet. In working the mine the larger masses are blasted, and the smaller ones loosened with the pick. The ore is removed from the rock, the latter is carted off to the dump, and the dry bone, mixed with more or less waste material, is carried to a neighboring stream. Here it is washed by an ingenious contrivance which thoroughly frees the ore from all sand and dirt. An Archimedes screw, turned by horsepower, revolves in a trough through which a stream of water is kept flowing. As the screw revolves it gradually works the ore up the gentle incline while the water runs down and carries with it all sand and dirt. Afterwards the dry bone is picked over by hand and the rock fragments thus separated. During the past season eighteen men were employed at the mine and the daily output was from fifteen to eighteen tons of ore. This would mean a yield of over 2,500 tons for six months and is probably about the annual production of the mine for the last

few years. The only zinc ore occurring in any amount at the Durango mine is the carbonate. Lead occurs in small amounts mixed with the zinc, this being one of the two instances noted in which this phenomenon appeared.

Fig. 70. Cleaning ore from the Durango zinc mine.

The Timber range yielded better in the vicinity of Durango than farther east, though some lead has been taken out at several points along it. As a whole the range has probably not been adequately prospected, and it is not improbable that it may again become an important producer. From its location well to the north, horizons lower than most of the Dubuque mines have been worked on it. At the same time it does not seem to have been worked to the base of the Galena, and lower bodies of ore may still be found in it.

In the vicinity of Durango a number of crevices have been opened up, but in general it is impracticable to correlate them with the crevices known farther east. The Snake diggings in the Ne. ¼ of Sec. 4, Dubuque Tp., may or may not represent a portion of the Timber range itself. On the accompanying map their general location only is indicated. The important crevice in which the iron ore at Durango is

found is not correlated to the east. The level in this crevice is opened along the upper limit of the flint beds, and certain test pits sunk along it show mineral at about the proper distance below the lower flint opening, which would indicate that in Iowa, as in Wisconsin, these horizons may be expected to be valuable.

Stewart's Park ranges.—South from the Timber range there is a considerable strip of barren country probably marking the crest of the Eagle Point anticline, though it is difficult to locate the anticline accurately under the upland. Apparently the course is from Eagle Point to Derby Grange (Se. ¼ Sec. 8). The Owens and Burton ranges would accordingly lie north of this anticline, while the Hard Bargain, Kanada or Kennedy, and other Park ranges would be immediately south of it.

The Owens was first struck in the winter of 1859–60 and in that and the following year is said to have yielded 2,000,000 pounds of mineral. The Burton was worked from 1865–68, and yielded about twice as much as the Owen. The Kanada gave about the same total as the Owen, and was worked in 1857–58. None of these crevices have yielded much east or west of this land and they all made mineral at intersections with north-souths. The Owens runs west and splits up into a lot of minor crevices. Beyond this point the main crevice has not been located. The Owen lead is described and figured in the *Dubuque Herald* of June 20, 1860. The figure given there has been redrawn and is reproduced.

Fig. 71. The Owen's lead. Redrawn from the Dubuque Herald, June 20, 1860.

In this figure No. 1 is the first shaft from which a drift was driven west to mineral at 5. No. 2 is a second shaft, 36 feet to mineral and 72 feet deeper to a second opening, with a

drift west 90 feet to a chimney, No. 3, with mineral in the top. The drift was carried on west 83 feet, where an uprise of 20 feet showed mineral again. Immediately under No. 8, a solid piece, estimated to weigh 40,000 pounds, was found. Under this was a narrow passage to a cave, No. 6, 12x30 feet and 24 feet high, filled up even with the entrance with rock and mineral. A new shaft, No. 7, was then being driven to reach this cave. At that time 200,000 pounds had been raised, 60,000 pounds in one week. On July 4th the *Herald* states that by crawling through a narrow crevice the ground had been explored some 250 feet farther west and another cave, or opening, found "loaded from floor to roof" with Galena. On July 25th the shaft No. 7 had reached the first cave, and in twenty-four hours 20,000 pounds of mineral had been raised. In all, 80,000 pounds had been raised the preceding week. On August 8th it was reported that the lead continued to yield 8,000 to 12,000 pounds per day.

The Collins crevice was worked west of the Owens and on nearly the same range. At one time, for a short period, it yielded 1,000 pounds of mineral per day. The main crevice in the district is, however, the Hard Bargain, which, starting from near the end of the present street car track, has been traced west a mile and a half to the land of James Rooney in Sw. ¼ Sec. 9. This crevice yielded a large amount of lead, and in 1834 supported a furnace, located about where the present park is now. This crevice is sometimes known as the "Old Million Lead," referring to the number of pounds of Galena taken from it.

Near the Hard Bargain is the Kanada, or Kennedy, as Whitney spells it. He gives the following description of the work at the time of his visit:*

This mine was producing largely in October, 1856. At that time the drift had been extended in the crevice to a distance of 330 feet from the shaft, which was 100 feet deep. The opening was about thirty-five feet in height, and the crevice extended upward in the cap rock, sometimes to a distance of fifteen feet or more. The Galena was said by the miners to have formed, for some distance, a solid sheet three and a half feet thick; in some places the rock was undecomposed; in

*Geol. Iowa (Hall), Vol. I, p. 454.

others, the crevice was filled with tumbling rock mixed with Galena. Over 1,000,000 pounds of ore had been taken from this rich deposit in the six months preceding our visit.

The Stewart Park ranges are not known to the west, though some mineral has been mined in section 7 on what was then

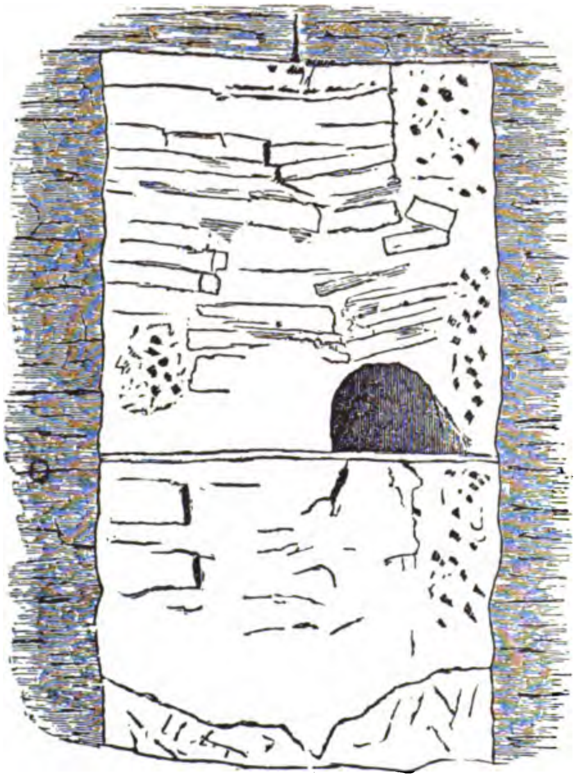


Fig. 72. Section of opening at Stewart and Bartlett's mine. (Whitney, figure 48.)

called the Saint John crevice. For a while a furnace (the Simpson) was maintained for smelting the lead found here, but this has not been operated since 1879.

Stewart and Bartlett's lode.—About a half mile south of the Hard Bargain is the Stewart and Bartlett, which has yielded altogether about 5,500,000 pounds of mineral. It is not now open. Whitney's description and figures are given below:*

This very interesting locality was still partially open for examination in 1854 and 5, although most of the lead had been taken out. Some of the appearances

*Geol. Iowa (Hall), Vol. I, p. 448.

observed here are peculiar, and throw some light on the mode of deposition of the ore, as well as on the action by which the crevices have been formed.

A space was worked out, open to-day, at one end of which a good exhibition was afforded of the mode of occurrence of the ore at this locality, and of the manner in which the strata had been impregnated with it, through the limited space called the opening; the rock remaining, in this part of the mine, nearly in its original position, not having been washed away. The wood cut, figure 48,[Fig. 72 of this report], represents the general appearance of the rock at this point. The width of theopening, between the walls, is about fifteen feet, and its vertical height not far from thirty-five feet. Within this space, it will be seen, that the strata are slightly bent downwards and broken in numerous places, leaving cavities between the fractured edges of the strata in which a portion of the ore has been deposited, as represented by the patches of oblique shading. The larger part of it, however, is collected along the walls of the opening, especially on the north side, where the rock is broken up into small pieces and somewhat decomposed, forming with the ore a brecciated ferruginous mass. The decomposition of the rock had evidently not proceeded quite as far in this case as in some others, or we should have had, instead of the mass of fractured strata still in place, a cave limited by the walls of the opening on each side and filled partially with detritus, clay and "tumbling rock," with fragments of galena scattered through it.

The workings at this locality have been on two different levels, in an irregular crevice, or two crevices connected together by flat openings. The excavations on the upper level follow an irregular crevice for several hundred feet, which had been entirely worked out before being examined by us, and which is said to have produced but little mineral. The lower drift is forty-two feet below the level of the upper, and was extended a little over 270 feet to the west of the shaft, and a considerable distance in the other direction, but how far, was not ascertained, as it had become filled up in that direction; probably over 800 feet. This lower drift runs in a crevice of varying width and height, sometimes widening out to twelve or fifteen feet, in other places closing within a few inches, and chiefly filled with clay and decomposed rock with fragments of ore. At the extremity of this drift the crevice comes to an abrupt termination, in a cavity such as would have been produced by the sinking down of a portion of the rock shaped something like a flat-bottomed boat, as represented in the annexed wood-cut, figure in 49, which the part left white indicates the vacant space, the flat upper part of which is fourteen feet wide and two and a half feet high, while the crevice runs off on each side at a steep angle, to an unknown depth. At the upper right hand corner, the crevice is seen continued upwards in the cap-rock: this probably connects with the crevice worked in the upper drift, as

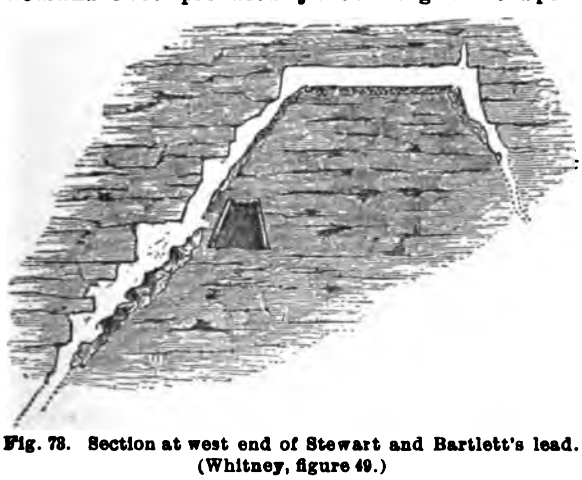


Fig. 73. Section at west end of Stewart and Bartlett's lead. (Whitney, figure 49.)

noticed before, and which was somewhat to the north of the lower one. The section is an interesting one, as showing how the formation of the crevice, in this portion of it at least, was due to a mechanical cause originating within and confined to a limited space in the rock.

We were informed that four millions of pounds of mineral had been taken from these excavations, which, when visited by us last year, seemed to have been entirely abandoned, and were rapidly filling up again with clay and sand.

Near this lead are the Ruly and the Timmons, both important producers, not now open.

Stewart's cave.—This cave is located at the intersection of a bunch of crevices, as indicated upon the accompanying sketch map (figure 74). It is reached by means of a shaft upon

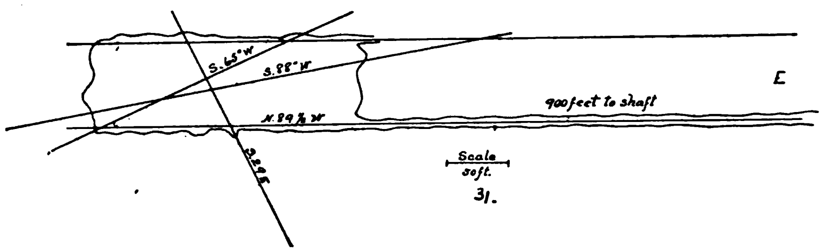


Fig. 74. Sketch map showing crevices which form the Stewart's cave.

an east-west crevice, whose south wall forms the south wall of the cave proper. The crevice itself is now open for 900 feet from the shaft to the cave. It shows along this distance a well marked crevice in the roof and is opened out to a width of from fourteen inches to three feet. Along much of the distance it is stoped out to a height of twenty-five to fifty feet. Drop shafts along its course go down forty feet in soft dolomitic sand without any sign of bottom, but show mineral at that depth near the water level. This mineral is in large cubes, "cog mineral," and is more abundant near the cave than farther east. The rust or ocher is more prominent near the shaft. The sands in the bottom of the crevice show cross-bedding and indicate actual movement of material along the crevice. The recent prospecting seems to have developed ore mainly at crevice intersections. The crevice forming the north side of the cave is, so far as known, barren.

The walls of the main crevice are weathered, as on an exposed cliff face, that is, so as to bring out very sharply the bedding planes. These correspond from side to side and there is no indication whatever of any faulting, either vertical or horizontal. The main crevice is cut by occasional cross-crevices both north-south, northeast-southwest and north-west-southeast. Occasionally two of these cross in the main crevice. These cross crevices are usually marked by vertical cracks in the wall rock, as much as three inches across and filled with dolomitic sand.

The cave itself is an irregular rectangle about 80x200 feet, and if it were cleared of fallen rock, it would be between forty and fifty feet high. The fallen rock, however, fills it nearly to the roof, which is flat and unbroken; along this roof the great east-west crevices are quite plainly marked. The north-souths are feebler. The bearings as given in the sketch were taken in the summer of 1899 and are magnetic.

The bottom of the cave cannot be reached, as water stands in it. The crevice and the cave proper are, however, quite dry. There is no drip, and no spar is seen in the roof and walls. The cave was discovered through a chimney on the main east-west marked on the sketch, and considerable Galena was taken from the crevice though not from the cave. The Galena occurred in bunches high in the top of the crevice and in loose fallen masses in the sand. No systematic work has been done here for some years, though a little prospecting has been carried on. This cave is sometimes known as the Redman cave, and another range, about 1,200 feet south and developed west of it, is known as the Redman range. About a quarter of a mile still farther south are the Moses, Leathers and still other ranges.

Levens.—This is one of the most important leads in the Dubuque region and is often known as the North Langworthy. It has been worked at intervals for nearly three miles. The eastern portion, lying within the city limits, was developed by James Langworthy and Brothers between the years 1830

and 1850. The South Langworthy lies about 300 feet south of it and is not to be confused with the Langworthy or Hancock range near Mercy Hospital. Henry Stout worked the Levens farther west in 1852–53, and still farther west, on Mineral lot 371, Tom Levens, in 1855, made one of the big strikes of the region in a cave. It is estimated that he raised about 5,000,000 pounds of Galena from this lot. Some black jack was also discovered, but being at that time valueless, no attention was paid to it. After Levens abandoned the property Peter Lormier, Anderson, Walsh & Co., and others took out a little mineral, and from time to time since a small amount of work has been done on it. It is estimated that in all perhaps 15,000,000 pounds of Galena have been taken from this crevice.

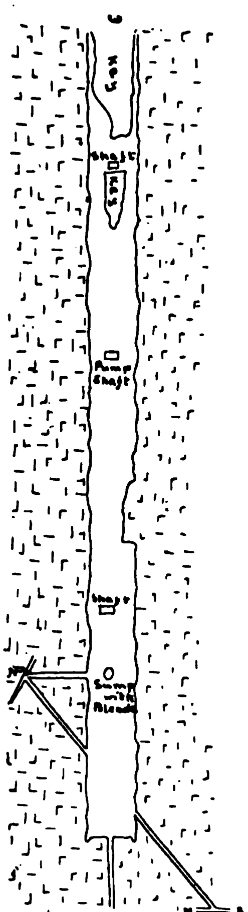


Fig. 75. Levens' cave as developed on Mineral lot 371.

Its general course is S. 83½° W. (Guilford) and it is said to vary but little from this course. The only portion of the work now open is the old Levens cave, which was visited in 1899 and again in 1900. This cave is on the Sw. ¼ of the Se. qr. of Sec. 15 (Tp. 89 N., R. II, E.). The discovery is said to have been made by crawling into the cave from the east, but later three shafts were sunk upon the cave. The middle shaft is the one from which the main mineral was hoisted. About fifty yards east of it is a shaft sunk in 1860 by Anderson & Co., and used later for a pump shaft, a forty-horse-power engine and pump being used. The work was, however, never carried much, if any, below the levels now free from water. At the intersection of the north-south, west of this, a prospect shaft showed good jack at a depth of

about forty feet. Not far beyond, the crevice narrows from forty feet to two feet and less for some distance. The main portion of the cave is twenty-five to thirty-five feet wide, and thirty to forty feet high. Except for the key rock west of the pump shaft it is all open for nearly 500 feet. There are two well marked crevices and the cave has been formed by the cutting away of the rock between them. On the Stout land, half to three-quarters of a mile west of here, the crevice opens out again into a great cave from which mineral has been taken.

Figure 75 is a rough sketch of the cave as developed on Mineral ot 1271. In connection with it the following description of the cave when first found may be read with interest.*

For a description of this very interesting locality, as it appeared when first discovered, we are indebted to C. Whittlesey, who visited it immediately after its discovery by Mr. Levens, and before it had been at all disturbed. This was in October 1850; it was first visited by one of us two years later, after about two million pounds of ore had been removed from it. The locality, as at first seen by Mr. Whittlesey, presented a narrow cave or crevice entering from the side of the hill, and capable of admitting, although in some places with great difficulty, the passage of a man: the crevice had a nearly east and west direction in general, with many small deflections from a straight course. We annex Mr. Whittlesey's description of his visit to the locality in question. After speaking of the difficulty of squeezing between the walls of the narrow and winding crevice, he goes on as follows: "We had not gone far in this uncomfortable manner, when a handsome cave appeared before us, illuminated by the lights in front. It was a square room, with a mud floor and a rock ceiling, along the middle of which was a seam, or vertical crevice, containing galena. This crevice was about two feet broad, the sides covered with mineral six to eight inches thick, leaving a space between the inner faces of the mineral, up which we could see several feet. There was about this crevice an entirely new feature, so far as I know. The solid mineral projected from this crevice downward, a foot to a foot and a half in a 'sheet' as they call it, eight to ten inches thick, and twenty-five to thirty feet long, spreading fan-like as it descended. (The annexed wood-cut, figure 50, will convey an idea of this peculiar and interesting feature:

a. Depending mass of galena.
b. Detritus and clay with galena.
c. Cap rock.
d. Galena limestone.

Fig. 76. Section of Levens' cave. (Whitney, figure 50.)

*Whitney, Geol. of Iowa (Hall), Vol. I, p. 450.

it represents a section across the cave at the point where the depending sheet of ore was obserAed, as described above.) A part of the way there were three sheets, two thick and heavy ones, with coarse irregular surfaces, composed of aggregated tubes from two to ten inches on a side, and one thin light sheet, the whole covered with oxide (carbonate?) of lead, and having, in consequence, a pure white color. This depending mass was wholly clear, except where it was attached to the rock above and projected downwards in space, the most rich and beautiful object I ever saw of a mineral kind. About two hundred feet more of twisting and squirming brought us to the leaden temple, where lay the fortune of our bold explorer. It is a cave, or pocket, some hundred and thirty feet long, twenty feet high in the dome, or cavern part and twenty to thirty feet wide, the sides and roof arched in an irregular manner. Probably it extends in this oval shape to a depth equal to the clear space above. The whole appears to have been ceiled with lead; and although its size is not as great as that of many (?) other mineral caves, the amount of galena in view at any one time is said to exceed that of any 'pocket' yet opened. Much of the lead lining the roof and sides had fallen down in immense blocks, some of them very recently. This mineral incrustation was, in places, two feet thick, and one of the fallen masses was estimated to weigh 23,000 pounds. In the mud and clay that formed the bottom, or floor, of this spacious room, they said that mineral would be found buried, or enclosed, in large lumps to the bottom, probably fifteen feet deeper."

Such was the appearance of things at this most interesting locality, certainly one of the most remarkable ever discovered, in 1850. In October, 1852, about 2,000,000 pounds of ore, worth, at the then current price of lead, about $50,000, had been removed, and there was still left in the mines about 1,500,000 pounds of ore, which was taken out in 1853 and 1854. A shaft had been sunk from the surface to strike the rich cave spoken of above, the top of which was reached at the depth of about ninety feet, and the bottom of the excavation was about forty-five feet deeper. The length to which the crevice had been traced was about 1,200 feet; and the cave-like expansion extended for nearly 300 feet, widening out in some places to twenty-five feet. The galena at this time could be seen, in some places, occupying a fissure extending upwards into the cap-rock: it also formed flat sheets running into the sides of the opening, in some places, with a thickness of three or four inches of solid ore; but by far the larger portion lay in loose masses in the bottom of the elliptical cave-like opening, mixed with clay, sand and loose masses of partially disintegrated limestone, called "tumbling rock." Besides the shell-like deposit of ore which lined the walls of this cave, as described by Mr. Whittlesey, there seem to have been horizontal layers which once extended through the opening; these had been broken up, and the rock surrounding them removed by the action of currents of water, of which the evidence could be seen in every part of the crevice, especially in the water worn and grooved lower surface of the caprock, and in the rounded edges and angles of the projectin gstrata of the sides of the opening

The Levens has been frequently described and referred to elsewhere. In the files of the local newspapers for the years between 1850 and 1860 there are many notes on it. The *Miners' Daily Express* of November 6, 1861, gives quite a full

description of it. At that time the cave had yielded about 1,000,000 pounds of mineral, and it was estimated that it would yield twice as much more. Altogether it has probably yielded between 10,000,000 and 15,000,000 pounds.

The workings are now being reopened by Bausche, Hosford & Co., who now (1900) have shafts open on both the Mettle ground (Mineral lot 371) and the Stout farm farther west. Their development work indicates that the zinc blende, discovered years ago, is developed at a number of places along the crevice in an opening approximately forty feet below the old workings. This opening bids fair to rival the upper opening in size. In order to work it, pumps will be necessary, and they with other machinery are now being installed.

Dubuque's cave.—Not far north of the Levens is a crevice supposed to have been discovered and worked by Julien Dubuque and hence called Dubuque's cave. This crevice has a general course of S. 82° W. (Magnetic, Guilford). It has been worked at many points; and in Mineral lot 452, where it intersects with the Sunflower, the first main crevice to the north, it produced nearly 500,000 pounds of Galena. On the eastern part of Mineral lot 376, it is said that some 300 tons of dry bone have been taken from it. Whitney estimates that, up to the time of his visit, the crevice had yielded 2,000,000 pounds of mineral.

In the winter of 1898-99, Mr. W. H. Guilford sunk a shaft upon this crevice east of the Mettle land, hoping to hit a quartering traced some distance from a shaft located to the northeast. The relative locations are indicated in the accompanying sketch (figure 77). The shaft was driven to a depth of ninety-eight feet, and at first, beneath the slate, showed dolomite with small flakes of disseminated lead and occasional bits of blende. Barytes, pyrite and calcite also occurred. The rock showed

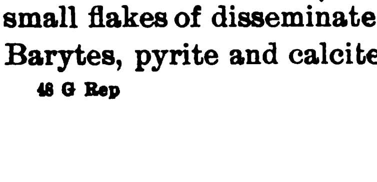


Fig 77. Guilford's prospect on the Dubuque's cave crevice.

a weak cleavage or rift in an east-west direction corresponding to the usual crevice. This continued to a depth of sixty-eight feet at which the usual first opening should have been found, but it gradually disappeared below, the rock becoming a hard blue dolomite with no signs of rift. Apparently the mineral vein traced towards this intersection had followed west on an intervening crevice to the next crossing, in this case, 150 feet beyond.

The Sunflower is an important crevice running at a considerable angle with the others in the region. (S. 79° 45′ W. Magnetic, Guilford.) At the east line of section 15 it is about 800 feet north of Levens. On Mineral lot 371 the Mettle Bros., in February of 1899, cleaned up an old shaft dug by Mr. W. H. Guilford about forty years earlier on the Sunflower, for mineral. It produced a little near the bottom of the shaft, but nothing of any great value. Dry bone was discovered at that time, but there was then no sale for it. The general situation is indicated in the accompanying sketch. (Figure 78.) The shaft is sixty-five feet deep to the main drift, and penetrates the Galena limestone twenty to twenty-five feet. Sixteen feet above the main drift is a cave in which a drift was carried through soft mud forty feet, without striking a wall rock. The shaft is now twelve feet below the main drift, and twenty-eight feet below this cave. The drift was cleaned up some 250 feet to the east, most of the way in soft mud washed in from the surface. At a distance of 200 feet from the shaft the dry bone set in, a smaller body showing at 100 feet. The bone continues to the end of the drift, and is ten to twelve feet in thickness. The width of the body is about twelve feet. At the face there is a narrow opening, and the roof is

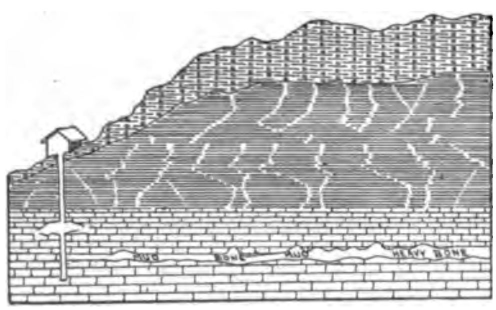


Fig. 78. Dry bone mine on Mettle land.

well defined, showing a dolomitic rock impregnated with dry bone. About 500 feet ahead of the face, and fifteen feet north, is another shaft with a level running west beyond this face. A short cross cut would cover the two workings.

Patch diggings.—There are a series of northeast-southwest quarterings lying between the Levens, or north Langworthy, and the level near their eastern limits.

Level.—This is one of the most important crevices in the Dubuque region. Its course is S. 81½° W. (Magnetic, Guilford). It has been worked for about one mile, and lies one-fourth of a mile south of the Levens. It is said to have yielded 10,000,000 pounds of ore. This crevice was opened up by level workings which were later on used as a source of water supply for the city. They are still connected with the city system, though now they do not alone furnish enough water to supply the demand. The level crevice is not supposed to be in itself so rich, but running southwest at a greater angle than is common, it picks up a number of minor crevices, each of which made a little bunch of mineral at the intersection. The level itself has not been found in the Patch diggings, though the quarterings are said to have been found richer about where its intersection should be, and on Seminary hill little crevices carrying mineral, mark its position.

It was upon the western end of the old level that the old shot tower shaft was located, and the only recent attempt at pumping for lead was made. This work was done by Capt. A. W. Hosford and E. T. Goldthorp in 1895. Mr. Leonard visited the mine and his description is given below:*

DUBUQUE LEAD MINING COMPANY.

The mine of this company is located one mile west of Dubuque and has been worked for about one year and a half. It is on the west end of the old Level Range, which has been followed for nearly three miles and has yielded considerable ore from various points along its length. At present (November, 1895) there are seventy-five men employed at the mine. The three shafts are 210 feet deep, with a steam hoist on one, and gins on the other two. The company have just erected a concentrator at the mine for the purpose of crushing and cleaning the ore. This was made necessary by the fact that in this mine much of the Galena occurs scattered through the rock, sometimes in particles of considerable size.

*Iowa Geol. Surv., Vol. VI, p. 48.

The limestone is crushed and the lead then separated from it. The ore-bearing dolomite forms a zone from two to four feet wide and containing an abundance of iron pyrites. This latter mineral is often found here crystallized in beautiful octahedrons with a length of from one-fourth to three-fourths inch. Besides being disseminated through the rock the Galena occurs in large masses in what is probably the fourth opening, and it likewise fills the crevice above for some distance. The ore body is apparently an extensive one; 700,000 pounds of lead have already been raised. Work in this mine is made possible only by the constant operation of a steam pump which keeps the water below the opening where the ore occurs, and thus allows the miners to reach the deposit.

A large amount of mineral was raised, a small mill was erected, and the ore was concentrated and smelted locally. The heavy expense incurred in pumping, together with the low price of lead then prevailing, caused the abandonment of the work when excellent ore was still in sight, going down into the water.

Kilbourne and Karrick.—These are two important crevices, neither of which is now being worked, lying about 300 feet apart, with the Karrick approximately one-quarter of a mile

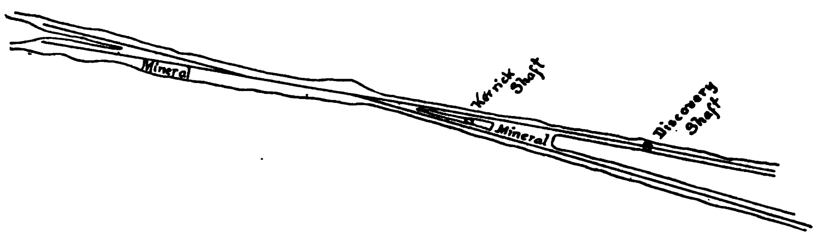


Fig. 79. Sketch of Karrick where the main body of lead was found.

south of the Level. The course of the Karrick is S. 89° 30′ W. (Guilford, Magnetic). It is cut by numerous northeast-southwest quarterings which seem to have led the mineral, originally worked in the Kilbourne, across into the Karrick. Some of the cross crevices come in at a very low angle. One, at what was known as the Polly shaft, coming in at N. 86° W., crosses the main crevice, making at the intersection a room thirty feet wide. The Karrick shaft proper was sunk on a key rock (figure 79), but was near a big body of mineral running for about 400 feet east and west. The Kilbourne is estimated to have yielded about 2,000,000 and the Karrick 10,000,000 pounds of mineral.

The Karrick was owned at the period of its heaviest development by the late Gen. George W. Jones, and his son, Mr. G. R. G. Jones kindly supplied the following note on the mine:

The mine was discovered by Capt. George Ord Karrick a little over forty years ago. Captain Karrick began prospecting on the old Kilbourne range, which is about 100 yards north of the Karrick. The Kilbourne was discovered by two English miners, and their prospect looked so well that my father, Gen. George W. Jones, bought it, paying $10,000 cash in gold for it. The Kilbourne proved to be a very rich lode. It contained solid bodies of ore as large as a bureau. After Captain Karrick had worked a while on the Kilbourne, which seemed to have given out in production of mineral, he came to the conclusion that the lead had gone somewhere else, and said that it had "jumped down" to the south. He then began prospecting on the present Karrick range, and soon struck ore which he followed west until the crevice opened out into very large dimensions, with numerous chimneys and caves. Four shafts were sunk on the Karrick, the "pump" shaft being the largest shaft in the Dubuque mines, five by ten feet. The water in the mines was very great in volume at that time. Now there is scarcely any water in the Karrick crevice. Captain Karrick began on the water with a chain pump worked by hand; then put on a gin with oxen for motive power and whiskey barrels for buckets. Horses were afterwards tried, and then a large steam pump, twelve inches, was erected. This pump was worked with a walking beam and large fly wheel. A battery of five steamboat boilers supplied the steam, and, as in those days coal was only to be had at Pittsburg, Penn., cord wood was used for the boilers. This fuel cost the company $100 per day and kept ten wagons hauling wood. When this pump was operating, water in mines one or two miles from the Karrick was lowered, and many wells and springs for miles around went dry, thus showing the Karrick to be a great central crevice. As many as 300 men were employed at one time on the Karrick mine. During the working of this mine the price of ore varied, but some thousands were sold from the Karrick for as high as $125 per 1,000 pounds. The Karrick has earned more than $800,000, all coming out of first opening. This mine has never been worked at a depth lower than 125 feet, and two or three openings have never been reached. It was the opinion of the U. S. mining engineers, who examined this mine over thirty years ago, that biggest mineral would be found still lower down. Deep mining has never been tried to any extent at Dubuque mines.

The mine was open at the time Whitney was in the region, and his notes on it are given below:*

Kerrick and Jones lode.—This is one of the most important and interesting deposits of lead which has been worked in recent years. The crevice is remarkable for its length and regularity as well as for its productiveness, it having already yielded over a million and a half of ore. It has almost exactly an east and west direction, the magnetic bearing between the shafts, proceeding in a westerly direction, being from No. 1 to No. 2, S. 85° W.; No. 2 to No. 3, S. 83° W.; No. 3 to No. 4, S. 83½° W. (the magnetic variation is about 8 E.). It has been opened for a length of nearly fifteen hundred feet, having a width from six to eight feet, except where divided into two portions by the "key-rock," when it widens out to twelve or fifteen.

*Whitney: Op. cit. p. 453.

At the time this locality was visited by us, in October 1857, the end of the drift going west was distant about three hundred feet from the engine shaft, and the crevice presented the appearance represented by the annexed section (figure 51), its width at this point being about six and its height about eight feet. The opening was filled with soft clay; the ore occupying a fissure extending upwards in the top of the drift, and having a width of nineteen inches (represented at *a* in the figure), all of which was solid galena, with the exception of a narrow, irregular space in the center, the ore having crystallized on both sides of the fissure, but not filling it up entirely. Twenty feet before reaching this point a solid sheet of mineral had been struck, which extended from the floor to the top of the crevice. Between this point and the shaft the crevice appears to have quite a variable height, the excavation having a height of forty or fifty feet, the crevice having extended upwards in the cap-rock and carried ore for a considerable distance. A section of the crevice at another point is represented in the annexed wood cut (figure 52), which shows the position of the so-called "key rock," an irregular mass of limestone remaining undecomposed along the center of the crevice, which divides it into two parts, as is frequently the case in the wide vertical openings: this disposition resembles the splitting of veins, so as to include large masses of rock, called, by the Cornish miners, "horses," and which are common in other mining regions.

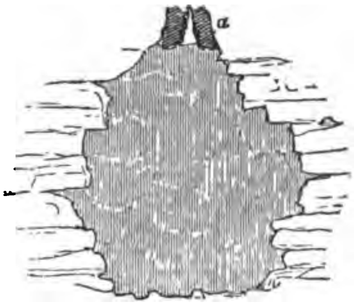


Fig. 80 Section at Karrick and Jones lode. (Whitney, figure 51.)

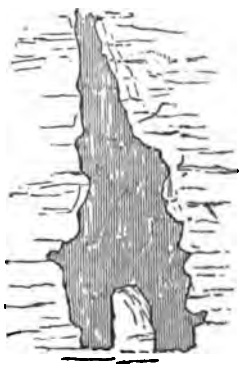


Fig. 81. Section showing key rock in the Karrick. (Whitney, figure 52.)

The workings on the crevice have been several times suspended and resumed, on account of the abundance of water, the shaft having reached a depth of 110 feet. After several abortive attempts to introduce new-fangled and ill-contrived machinery for pumping, a steam engine was erected which operated a suitable pump with twenty-one inch lifts, raising 700 gallons per minute and with the aid of which it was intended to sinkthe shaft twelve feet deeper.

This was the only locality, at this time, where steam power was in use on this side of the river for draining a mine. Another engine was erected at Riley's lode, a few rods south of this, and which has been worked for some years, over an extent of several hundred feet longitudinally and to a depth of 137 feet, and much mineral raised; 2,000,000, it is said. The crevice, which was not accessible, was found to be almost exactly parallel with that of Kerrick & Jones, its mean direction being N. 86° E., S. 86° W., magnetic.

The *Dubuque Herald* of June 20, 1860, speaks of the work having ceased, pending some new financial arrangement, and deplores the heavy investment in pumps therefore standing

idle. The mine has not been worked for some years but a shaft on the Kerrick is now open on the Ahern ground and a good grade of zinc blende is shown at the bottom.

McGowen and Cunningham crevices.—These are two important and interesting crevices running through sections 22 and 23. The course of the former is N. 72° 30′ W., and the latter N 85° W. (Magnetic, Guilford.) They intersect in Mineral lot 179, and east of that the McGowen is not known, though the Cunningham is worked some distance under the city. Messrs James Hird & Son have, for some years, worked this crevice for dry bone. Mr. Leonard's description of their workings is as follows:*

THE M'GOWEN CREVICE.

Direction N. 86° W. This crevice is located just west of Dubuque and was formerly operated for lead, but for the past eight years it has produced zinc ore. The shaft is 112 feet deep. Only the first of the openings present has been explored. The greater portion is above the cap rock and is called by the miners a "cap rock" opening. The expanded crevice is a large one, the average height being forty to fifty feet, and the width four to ten feet. In some portions it opens into caves with twice the above width, and these are filled with zinc ore mixed with clay and more or less rock, much as in the Durango mine. Some twelve feet west of the shaft the lead gave out and a few yards beyond zinc carbonate began to appear and soon occupied the entire opening. At one point almost the whole cavity is filled by the "keyrock," leaving only a narrow space on either side for the ore."

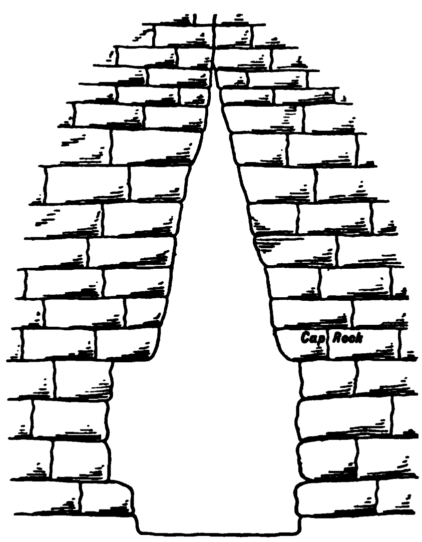


Fig. 83. McGowen crevice showing cap rock opening.

Rake Pocket.—This is an important crevice a short distance south of the Cunningham. Its course is given at S. 86° 15′ W. It has been worked on the Ahern ground, Mineral lot 262, and east under the city, but the intermediate ground and the territory to the west have not been opened up. On the Ahern ground

* Leonard: Op. cit. p. 48.

is the Halpin mine, which yielded 967,265 pounds of galena in 1898, besides a considerable amount in 1897.

The situation at this mine is illustrated in the accompanying sketch (figure 83). The shaft is 116 feet deep, and to the east the ore has been stoped out for a height of about sixty feet, and

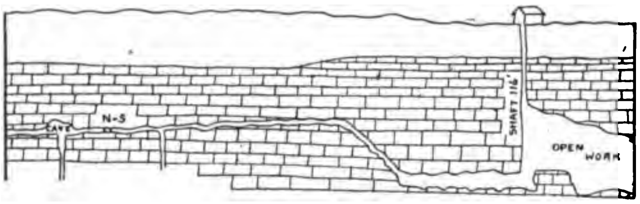


FIG. 83. Halpin mine on Rake Pocket crevice.

twelve feet wide, for a distance of approximately 100 feet. The ore occurred as large lumps of Galena mixed with sand and a little fallen rock. West of the shaft, for perhaps 100 feet, the opening is about six to eight feet high and eight feet wide; it carried ore in loose dolomitic sand. Beyond this there is a twenty-foot up-rise to a narrow drift driven along the cap for 300 feet. Drop shafts from this drift show mineral at the water level, which is about the same as at the shaft. In a small cave near the cap some 4,000 pounds of mineral were found in one bunch. Near this cave there is a small opening along a north-south crevice which intersects five parallel east-west crevices; these last are only partially explored.

An attempt to handle the water here by barrel proved useless, and it will be necessary to put on pumps if the work is to be carried any deeper.

Julien Avenue crevices.—About a quarter of a mile south of the Rake Pocket, and near Julien avenue, is a group of important crevices of which the Fourteenth street, the Avenue Top or McNulty, the Black, Falkner, and Fanning are best known. These have all been worked for some years and the first three named are now supporting important mines.

In figure 84 the workings of the Fourteenth street mine are represented. The general course of the crevice is S. 85° W. (Magnetic). The shaft is 150 feet deep and stops at water level

in the lower opening. It is nineteen feet from the top of the upper opening to the bottom of the lower. The mine has been worked mainly for dry bone and has produced as much as a carload a day. On the upper level the opening has been followed west several hundred feet, and a big chimney was found

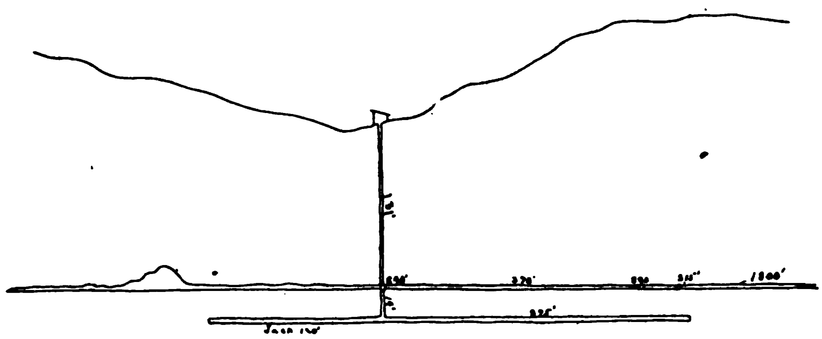


Fig. 84. Fourteenth Street mine.

as indicated in the sketch. From the shaft a drift was run south ninety feet and yielded good dry bone all the way. East of this level, at a distance of 370 feet, a level has been run south thirty-five feet, and twenty feet beyond it a second has been carried south fifteen feet. Beyond this the crevice has been followed 1,300 feet. These various entries at this level all yielded good dry bone and show much mill dirt yet in the walls. They average about four by six in cross section, and the wall rock is said to run 18 to 20 per cent of dry bone.

The second level has been driven approximately 160 feet west, with a cross section 4x4, and 375 feet east. Dry bone was taken out in driving each entry, and for a distance of 120 feet along the west entry an excellent grade of blende shows in the walls and bottoms. Messrs. Mays & Co. have recently taken hold of this property, erected a steam hoist, and are now sinking and driving east. A face, 6x8 feet in cross section, is carried to the east, showing a mixed jack and dry bone ore. Recently a very fine body of dry bone has been found. Deep drop shafts, driven from the upper level about 1,000 feet east of the shaft, are said to have been carried down to the flint, and to have shown ore to that depth.

A few hundred feet south of the Fourteenth street workings is one of the most important crevices in the region. It is known as the McNulty, or Avenue Top. The eastern portion of the crevice is now controlled by the Avenue Top Mining company, while the western portion belongs to the Bush Mining company.

The Avenue Top mine was first opened in 1875 by McNulty, Burt & Co. in search of lead. A large body of Galena was found on what is now the upper level, immediately east of the shaft, and 130 feet below the surface. To this day Galena may be seen running off in small flats between the ledges of clean Galena limestone. In the further search for lead a thin sheet of mineral was followed south 350 feet to the Black crevice, but it made nothing of value either in the north-south, or in the Black crevice. About midway two east-west crevices were crossed about thirty feet apart. A quartering a short distance north should intersect with these about fifty feet west and may make mineral. The general relation of these workings is shown on the accompanying ground plan, figure 85.

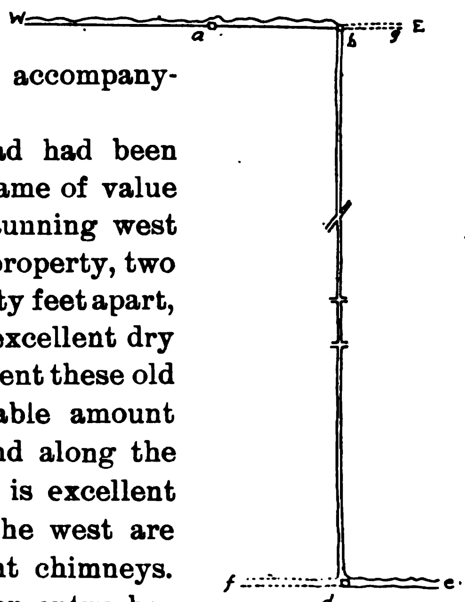


Fig. 85. Ground plan of Avenue Top mine.

Some years after the lead had been mined out, the dry bone became of value and work was resumed. Running west from the shaft to the Bush property, two levels were driven about thirty feet apart, and a very large amount of excellent dry bone was taken out. At present these old workings show a considerable amount of lean ore yet unmined, and along the bottom, in the water, there is excellent jack. These workings to the west are large and show very frequent chimneys. East of the shaft the upper entry has been opened up a long distance, but it did not yield so well. Eighty feet from the bottom of the shaft,

a drop shaft, sixteen feet deep, connects with the north-south already mentioned as running over the Black crevice. On the ground plan, figure 85, this is represented at *b*. In the same figure *a* indicates the location of the main shaft, *g* the abandoned eastern workings in the McNulty crevice, *f* the closed upper western workings on the upper level of the Black crevice, *d* a second drop shaft, thirty feet to the present workings on the Black crevice, and *e* the forehead on the latter. In the east-west cross section of the McNulty crevice, figure 86, the letters correspond to those in the previous figure, *c* representing the bottom of the first drop shaft, the one connecting the main east workings with the north-south crossing.

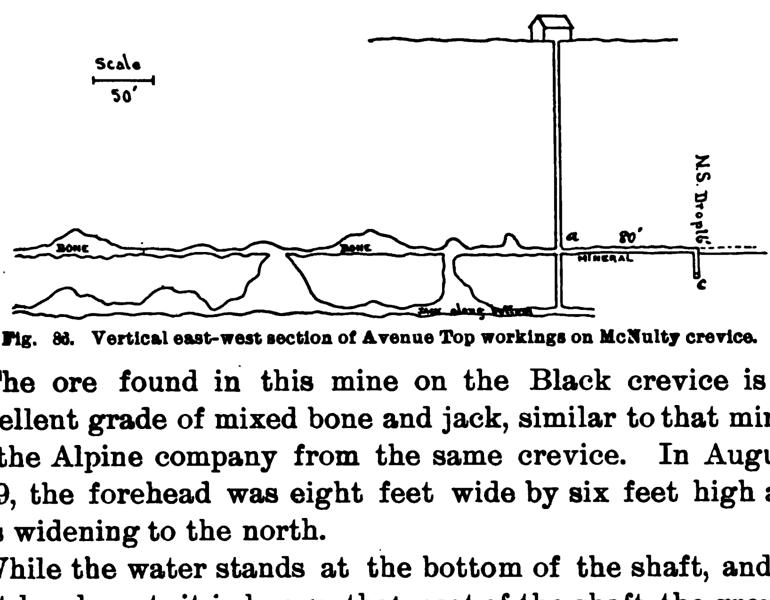


Fig. 86. Vertical east-west section of Avenue Top workings on McNulty crevice.

The ore found in this mine on the Black crevice is an excellent grade of mixed bone and jack, similar to that mined by the Alpine company from the same crevice. In August, 1899, the forehead was eight feet wide by six feet high and was widening to the north.

While the water stands at the bottom of the shaft, and at that level west, it is known that, east of the shaft, the ground is dry to a considerable depth. The present workings of the company on the Black crevice show no water, though sixteen feet below the water level at the main shaft. The work in this and neighboring mines indicates that there is a north-south bar approximately under Nevada street, and that east of that the water level is at least seventy feet lower than to

the west. It is proposed to cut this bar and drain the western country, so as to allow the mining of the jack now in the water in the Avenue Top and Bush workings.

The Bush mine is located upon the western extension of the McNulty crevice, and the upper levels of the two mines have been driven through to connect. Figure 87 shows a verti-

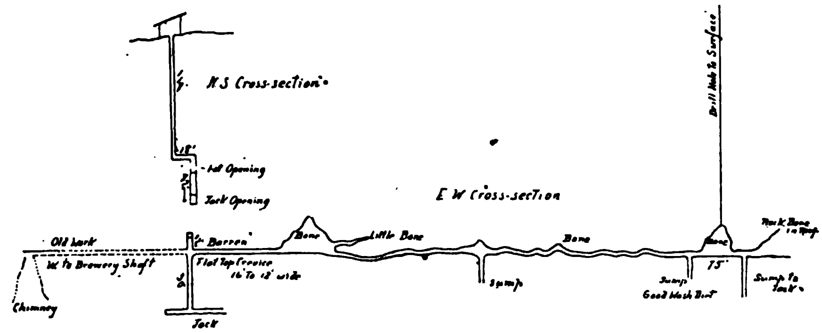


Fig. 87. Vertical cross-sections of the Bush mine, 1899.

cal east-west section of the present workings. Unfortunately the shaft was sunk eighteen feet south of the crevice to the top opening. At this point a level connects it with a drop shaft on the crevice proper. In the upper portion of the sketch is a north-south cross-section showing this.

Along the upper level a considerable amount of dry bone has been taken out east of the shaft, and some lean ore remains. Several sump shafts driven to water level show that the jack seen in the Avenue Top, runs west under this property. West the work is now stowed up, but it was formerly open to a connection with certain old workings near the Western brewery, from which a considerable amount of mineral was taken. At the time of the work the water stood up to the bottom of this upper level. Later work to the east has lowered this, and as a result a second level is now being run on the Bush ground thirty feet below. This level has a forehead approximately 4x5 feet in either direction, and is yielding a good grade of jack mixed with a little bone.

The Black crevice, already mentioned in connection with the description of the Avenue Top mine, extends from the

edge of the bluffs west to the Brewery and beyond. It is a remarkably large open crevice, is said to have yielded 500,000 pounds of mineral at the Brewery, and 1,000,000 pounds still farther west. A portion of the crevice, under the Brewery grounds, was formerly used for a malting room, and certain famous underground dinners and dances have been held in it. One such dinner is described in the *Dubuque Herald* of August 22, 1860. The eastern portion of the crevice has yielded dry bone heavily and is now producing a mixed bone and jack. This portion of the crevice, except as noted below, belongs to, and is mined by, the Alpine Zinc Mining company. A certain portion of the crevice underlying the Dillrance property, is in dispute between the Alpine and Avenue Top companies, and in the meantime is in possession of the latter. The Alpine company has now four shafts upon the crevice. The quarry shaft at the eastern end produced four cars of bone in sinking the shaft, but it has never been worked to any extent. It is ninety feet deep. The Fifth street shaft is 155 feet to the bottom of the shaft, and 110 feet to the bottom of the top opening, in which most of the work has been done. The Alpine, which is the main shaft and is named from the street upon which it is located, is 127 feet from the engine floor, 140 feet from the loading platform to the bottom of the top opening, and about fifty feet below that to the present bottom of the mine. The Baxter shaft, located near the water tower and west of the disputed ground, is 110 feet deep and shows jack just above the water level. In all, the company holdings cover nearly a mile along this crevice.

For convenience in comparison the following table of elevations is inserted at this point:

ELEVATIONS OF SURFACE ABOVE SEA LEVEL.		LEVELS OF VARIOUS OPENINGS.					
Black crevice—							
Baxter	886	775					
Avenue Top	875			730		700	
Alpine	845				718		668
Fifth Street	815					705	660
Top opening exposed on Eighth St.					715		
Quarry shaft	745						655
McNulty crevice—							
Avenue Top	875		745		715		
Bush	855			729		700	
Fourteenth Street	820						650–670
Top of Galena exposed on Eighth St.	765						
Flint beds, top	645						
Probable base of Galena	560						

From a study of these figures it is evident that the heavy body of jack found in the Fourteenth street, the Quarry, Fifth street and the Alpine shafts all belong to one general horizon. The slight differences in level are no greater than occur along either of the crevices within the limits of a single mine. In a general way this horizon doubtless corresponds to the one commonly called the "third" opening, though the upper portion represents the "second" at the Alpine, and the "first" in the Fourteenth street mines. The next group of openings range all the way from 700 to 745 feet above sea level. Whether they are really the same or not is a question. In the Avenue Top work on the McNulty crevice the two openings chimney together and the top one has been connected with the top one in the Bush (729 A. T.). The lower one is called the "second" in the Avenue Top, and the "four foot" in the Bush, where it is thought to be above the true "second." As a matter of fact, it is slightly lower in the Bush than in the Avenue Top. The upper opening in the latter undoubtedly corresponds with the one seen in the quarry just off Eighth street and found at the same level in the Alpine workings on the Black crevice. The upper work in the same crevice on the Avenue Top ground is a little

lower, and the lower work, where ore is now being mined, is several feet above the stopes now being driven by the Alpine. It is obvious that the opening worked in the Quarry shaft is really the lowest opening worked in the others, and that the opening in the Baxter, if the depth of that shaft be given correctly, is too high to allow it to be correlated with the work farther east.

The flint beds, which as elsewhere noted mark a probable ore horizon, lie below the jack openings worked, and the base of the galena, marked in Wisconsin by the "Pipe Clay" opening, will be found 92, 100, 105, 90 and 140 feet below the present shaft bottoms in the Alpine, Fifth street, Quarry, Fourteenth street, and Bush mines respectively.

The Alpine mine is at present the largest and best equipped mine in the district. It was worked for some years by the firm of Trueb, Southwell & Co.; but since February, 1899, it has passed under the present name. The equipment includes a power hoist, air compress or power drill, dynamo and a system of electric lights. The current from the dynamo is used for firing the shots. At present work is being carried west from the main shaft. The Fifth street shaft, some 500 feet east of the Alpine is equipped with a horse gin, but is not operated continuously. In sinking the Alpine shaft several thousand pounds of lead ore were found, but below, the ores have been zinc. Dry bone has been shipped for years from the upper opening. At the second opening, which is quite large and well developed, the ore pitches to the north and broadens out. There are indications of a similar pitch to the south, though the ore has not as yet been followed in this direction. The main stopes are accordingly now north of the shaft. A north-south cross section of the shaft, showing its relations to the

ore, is given in figure 88. At present the stope is sixteen feet wide and the face twenty feet high. The ore has been followed approximately 400 feet west or to the disputed ground. The bottom shows even better ore, clearer jack and less bone. In the Fifth street and the Quarry shafts the same ore body is found at the proper horizon, while at the Baxter shaft good ore occurs nearly 100 feet above this level. The Alpine workings, and those east of that shaft, are east of the bar already mentioned, and accordingly are not troubled with water. There is evidently a very large amount of good ore yet to be mined here, and under the present active management the property may be expected to develop into an important mine.

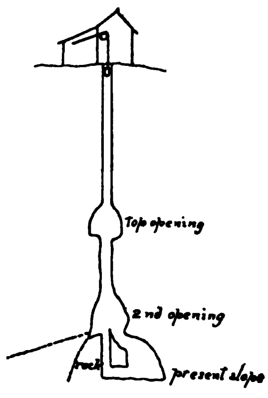
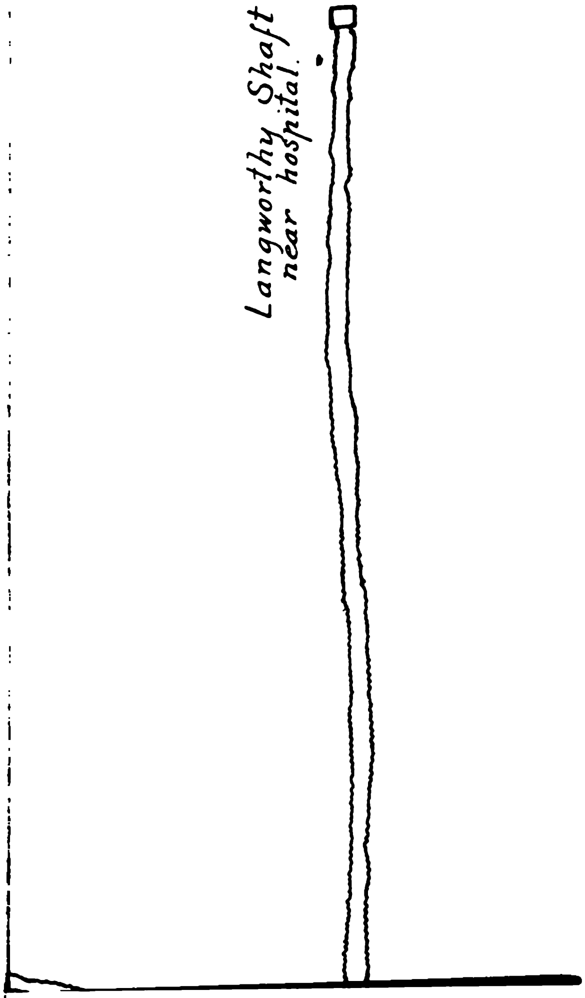


Fig. 88. Cross section of Black crevice at Alpine shaft. 1899.

About 150 feet south of the Black crevice is the Fanning, which was very extensively worked in 1856–57. More than 200 men are said to have been employed upon it at that time. It is not worked as far east as the Black crevice is. Three hundred feet beyond it, and nearly parallel, is the Aulkner, which is estimated to have yielded about 2,000,000 pounds of mineral. To the east this crevice loses its identity, and to the west, it with the Fanning, Black, McNulty andother crevices of this group, runs into the great country of open underground work known as the McPoland pond.

Langworthy and Kelly.—South from the group of crevices just described the next important group is the Langworthy and Kelly. As usual these crevices were, some years since, worked for lead, but they are now open as zinc mines. They are about 300 feet apart, and the Langworthy has been worked for several miles along its course. It is said to have yielded about 6,000,000 pounds of galena. The Kelly has been worked from the cathedral west into section 27, where there are a number of quarterings connecting it with the

Plate ix.



Langworthy. It closes up tight at intervals, but, altogether it has proven a most reliable crevice. Up to February, 1854, the Langworthy, Kelly and Cardiff were estimated to have yielded some 10,000,000 pounds of mineral. The Langworthy is occasionally known as the Hancock.

At present these crevices are being worked at three points. Near Mercy hospital Dr. H. G. Knapp has an excellent body of jack ore on the Kelly, entrance being through the Langworthy as shown on the accompanying map. West of here a new company is at work on the Langworthy, and on Brad street Boyle & Company are working the same crevice for dry bone.

At the Knapp mine the jack is found on the Kelly at a depth of 147 feet from the surface, or 110 feet in the rock. This would place the ore body at about 660 A. T., or about the same level as the jack found in the Alpine and neighboring mines. The work is east of the bar before mentioned and is accordingly dry. When visited in the fall of 1899, the entry was approximately sixty-five feet long in an east-west direction. At the east end the face showed a body of jack widening from a few inches only in the roof to about three feet at the bottom, the entry being seven feet high. A sketch of the ore (figure 89) as seen in the roof seam is given below, *a* representing clear white crystals of calcite, *b* the crystalline calcite commonly called tiff, *c* the black blende showing occasional faces of the rhombic dodecahedron, and the whole surrounded by ordinary earthy dolomite. The ore consists of a dolomite much cut by solution, with the solution cavities later filled with blende. It is one of the cleanest and best ores so far mined in the region. The vein shows as usual no sign of faulting, selvage or other phenomena common to the fissure veins of the west. West of the drop shaft by which the jack is reached, the cap rock is well

Fig. 89. Blende and calcite in the Kel'y range.

developed though the crevice shows plainly. Beyond this the jack is mixed with a little bone. The blende was found by means of a drop shaft from the old mineral and bone workings on the Kelly, which are thirty feet above its level. These workings are the ones shown on the accompanying map (Plate IX) reproduced here to give an exact idea of the way these crevices run. The map is from surveys made by Mr. W. H. Guilford and is published by the courtesy of Dr. H. G. Knapp.

On Brad street the Langworthy crevice is being worked by Boyle & Company for dry bone. The accompanying sketch map (figure 90) is a ground plan of their workings as they existed in the summer of 1898. The shaft now open is located on a north-south some forty feet east of the intersection of two important crevices which come together at a low angle. Some years ago a shaft was opened at this intersection and the mine was worked for mineral. The dry bone was discovered at that time, but as it had no value the entries were driven through it and the material excavated was dumped into swamps and stowed as waste. Along both of the crevices there are frequent chimneys running up six to twenty-five feet. Where there are no chimneys the crevice is sixteen inches to four feet wide, with a flat cap rock showing a narrow vertical seam. The crevice opens occasionally to a width of ten feet. The walls show weathered Galena limestone in ledges about ten inches thick, the weathering having proceeded farther along the bedding planes. The dry bone makes in flats along these planes, resembling in appearance and position the cherty partings usual in limestone formations. Much of the crevice is filled with a breccia composed of blocks of Galena limestone fallen in from the sides. One piece, 1x3x4 feet in diameter, was measured. These blocks

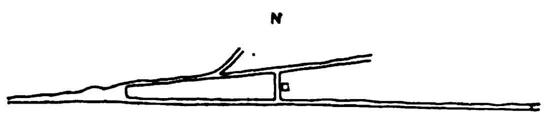


Fig. 90. Bradstreet mine on Langworthy crevice.

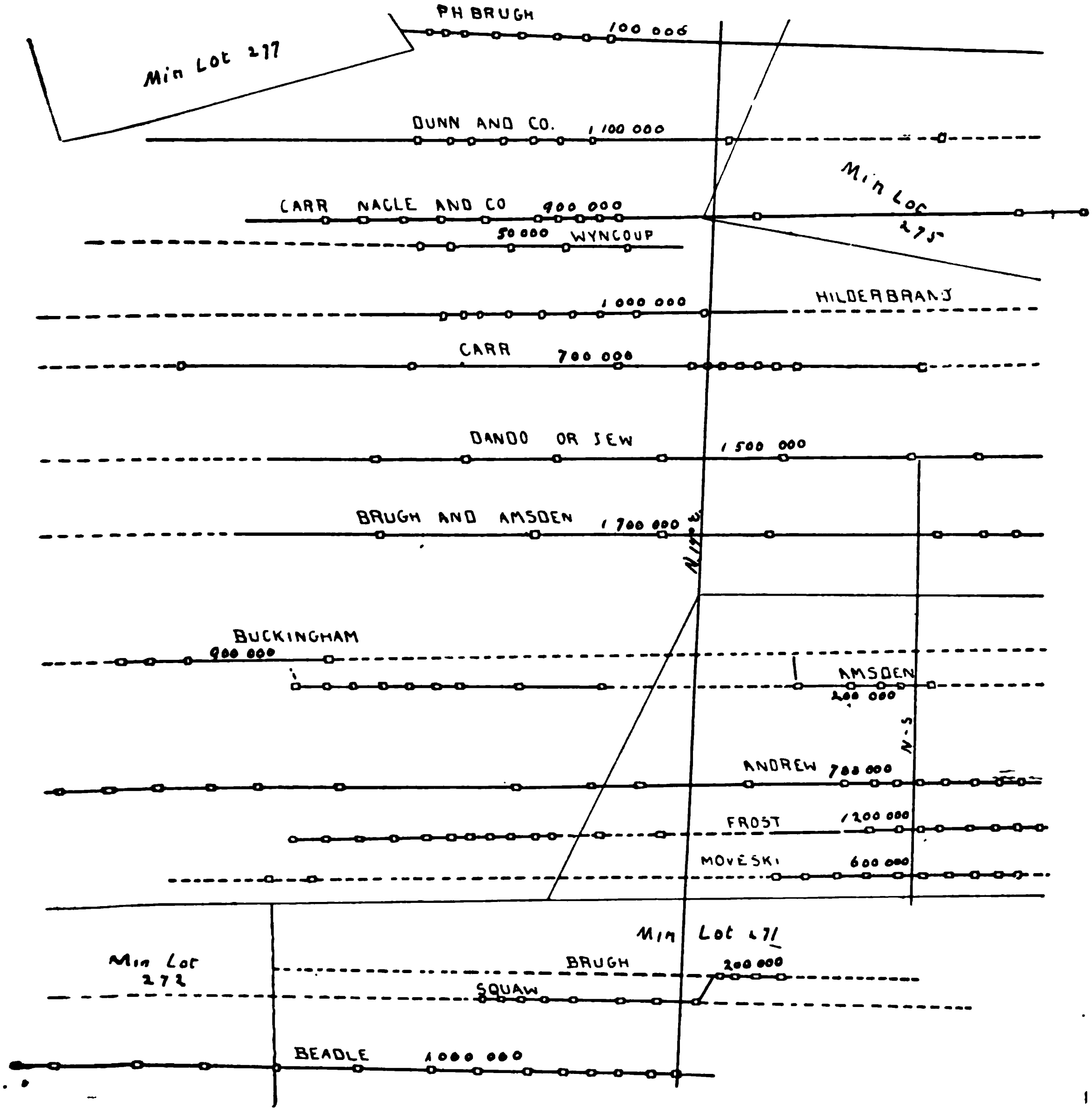


Plate X. Sketch map of main crevice in the Pike's Peak region.

stand at all angles as in a talus heap. Occasionally a block is level and continuous with the bedding at the side, being supported by narrow rock pillars. The matrix of this conglomerate is largely dry bone. There is also much ochre; and where water runs down the sides they are coated with calcite. There are no signs of galena, blende or pyrite. There is a considerable amount of coarse dolomitic sand, occasionally showing cross-bedding. Apparently, as the walls weathered back, the harder and undissolved pieces of rock caved in. These were later cemented by dry bone, and finally freely moving waters deposited mechanically the dolomitic sands.

Rabbit Hollow mines.—South of the Langworthy there are a number of important crevices among which the Slater, Peacock. Madden and others may be mentioned. Near the end of the Dodge street car line there are a number of small mines, among which the one known as the Rabbit Hollow mine is at present the most important.

Center Grove mines.—In the general vicinity of Center Grove (Sw. ¼ Sec. 27) there has been more or less mining for years. On Mineral lot 243, a large number of shallow shafts were, at one time, opened for lead. These were so close together that at present the lot looks as if it had been completely burrowed. The Slater crevice is now opened up on the Luther place and has yielded some mineral. A number of good crevices are known to underlie the Guilford land, Mineral lot 237. Between here and the end of the street car line are a number of small prospects, and the Sevastopol or West Dubuque mine, a former heavy producer, is now being reopened.

Pike's Peak.—This name is applied to the mines occurring on the Se. ¼ of Sec. 33 and the adjacent lands. The name had its origin in the circumstance that the mines here were discovered and extensively worked for lead about the time of the Pike's Peak excitement in Colorado. A sketch showing the general location of the leading crevices with their estimated production, as compiled by Mr. W. H. Guilford and Mr. J. R.

Miller, is given in Plate X. Some of these crevices are known to extend under the land to the east and west, and others are as yet unproven under the adjacent territory. All of these crevices were extensively worked for lead ore, and in many of them good ore was left in the bottom when the work was abandoned because of the water. In others black jack is known to be present in quantity.

In 1899 a partnership under the name of the Pike's Peak Mining company, undertook to unwater some of these mines for the zinc ore. A pump was installed on the Brugh and Amsden range, and later an old shaft on the Dando or Jew was opened up. The pump had a rated capacity of 300 gallons per minute and after a few weeks took the water level down sixty feet. This uncovered some galena and a considerable amount of black jack. The latter occurs in solution cavities in the blue Galena limestone, mixed with pyrite and the galena, mixed with some blende, is below. Similar ore is found on the Jew crevice. Several hundred tons of the ore have been raised, and considerable bodies have been proven. The ore must be concentrated before it can be used, and the large amount of pyrite present makes it difficult to make a clean concentrate. Many of the other ranges are known to be valuable and will be opened up.

On the Locky land, north of Pike's Peak region proper, are the Old Rock Lead, the Locky and other crevices, including one worked by Messrs. Hird. These crevices have all yielded dry bone and show more or less jack. An effort is now being made to unwater the Locky for the sake of the blende. A lift pump driven by horse power has been installed, and a good body of jack and bone has been uncovered.

Other crevices.—In addition to the crevices and mines specifically described there are a large number of others, including the Floyd, Goose, Horn, Smith and Stewart, Booth and Carter, Ames, McNair, McKenzie, Iron Rust, Driscoll and McNamara, the Whisky Hill or Seminary ranges, the Peru diggings and the Rockdale and Key West mines. Among the

latter the Kane Bros. mine, opened in 1898, is interesting and important. This mine is located at the eastern edge of Key West and at the head of the Rockdale hill. A sketch of the workings, as open when visited in 1898, is shown in figure 91. The mine is now reached by means of the shaft *a*, which is about fifty feet deep. This one was discovered, however, by crawling in along the crevice *f* from some old workings to the east. The east-west crevices are connected by narrow north-souths, such as *e* and *d*. At the drop shaft, at the north end of *e*, there is a difference of five feet in level, the northern openings being higher. This portion of the workings lies about six feet below the top of the Galena limestone, but west from the main shaft *a*, the work rises, and at *b* the shales themselves form the roof of a small cave.

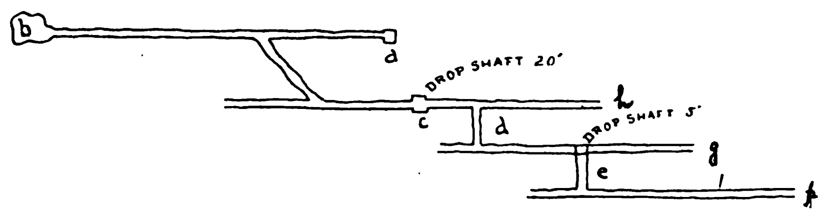


Fig. 91. Ground plan of Kane Bros. mine.

Galena was found along the crevice from *a* to *b*, but the main mineral comes from the crevice *h*. This opening is made by two parallel crevices, as is indicated in figure 92. The roof is flat, the cap well defined, and the two crevices show above as mere fractures. A drop shaft at *c* shows the presence of a key rock dividing the two as they go down. When first discovered *h* was an open space three to five feet wide and twelve to twenty-four inches deep with loose dolomitic sand in the bottom. The walls and roof showed clusters of galena crystals, and pieces of mineral were found on and in the sand. From a distance of some forty feet approximately 50,000 pounds of mineral were taken. The ore may still be seen in this and the other crevices in thin sheets, running out

along the bedding planes, and in druses in the cap and wall rocks. Bits of the rock broken open show pieces of mineral in apparently undisturbed dolomite. The galena usually takes the form of cubes, occasionally with octahedral truncations. It occurs in large crystals, some of the cubes having three inch faces. The present workings are considerably above the ordinary first opening level. Whether open ground will be found below is as yet unknown.

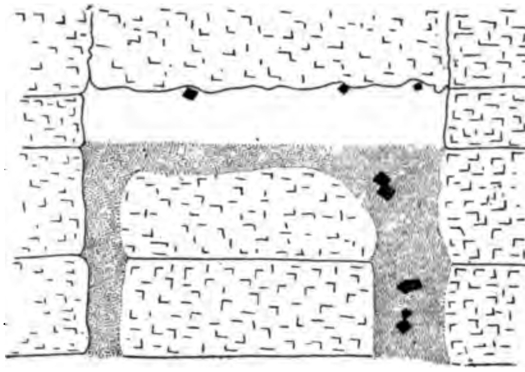


Fig. 92. Occurrence of galena in Kane Bros. mine.

Another interesting little mine, interesting, because it is so typical of the general work of the region, is the McPoland and Basler, visited in 1898. It is located in West Dubuque, near the end of the Julien avenue car line. The shaft is three by six feet in cross section, ninety feet deep, with forty feet in the Galena limestone. It is timbered down to the rock with two-inch lumber placed on edge and staid in place with one-inch strips. A ladder fastened to one end, a windlass, rope and bucket, a board roof supported on poles at the corners, and a few picks, shovels and hand drills, complete the equipment. Two men work the mine. One stays above and hoists, the other works below, drilling and tramming out the ore and rock. The figure (93) given below shows the plan of the work which follows various small crevices. The numbers give approximate distances in feet. Running southwest, a sheet of

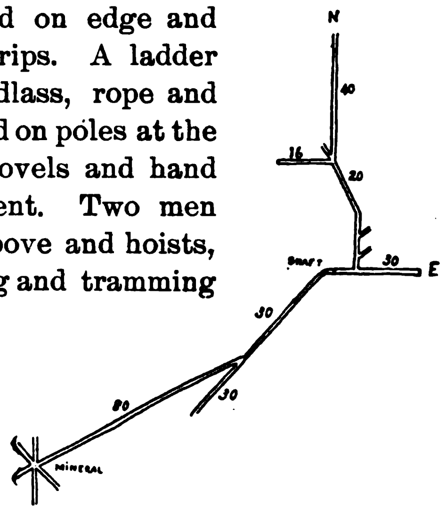


Fig. 93. McPoland and Basler mine.

mineral, one-half an inch thick, was followed. It lay between dolomitic walls which were softened and weathered to a sandy consistency for a total thickness of about three inches. This was picked out by the miner, much as a shearing cut is made in coal mining, and then a blast was placed so as to break the rock towards the cut. In this way an entry, about five feet high by two wide, was driven at a cost of approximately $1 a foot.

At the extreme southwest of the mine, as sketched (figure 93), an intersection of several crevices was discovered where the rock was badly decayed and contained considerable mineral. This showed usually as cubes and was in softened and weathered portions of the dolomite. For example in figure 94, *a* represents the galena, *b* the sandy dolomite and *c* the weathered rock. Here, as in the narrow sheet, it seems that the ore was deposited in the rock before the weathering took place. This is the more evident in the case of the vertical sheets where the mineral has the exact form of the common narrow cracks and the plane between the sheet of mineral and the country rock would be a natural one for the circulation of water and consequent decay of the rocks.

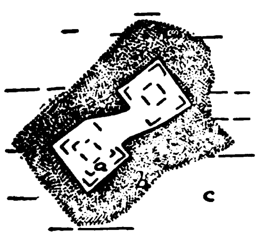


Fig. 94. Occurrence of galena in McPoland & Basler mine.

Mines away from Dubuque.—While the main mining has been done in the immediate vicinity of Dubuque, there are traces of mineral at other points in the county. At Sherrill Mound and elsewhere in Jefferson township a considerable amount of lead has been taken out and at the first named place the old dumps show the presence of dry bone and black jack. In Mosalem township, near Rice's and Ball's caves, there is abundant float, and some ore has been found. In regard to these and other cases it can only be said that no important ore bodies have yet been developed. The region is similar, in all essential particulars, to that near Dubuque where the heavy ore bodies occur. It is not unlikely that

adequate prospecting would develop important leads, but here, as near Dubuque, it is to be expected that the ore will be irregularly distributed and that much of the rock will be barren. While traces of minerals are everywhere common, the concentration of minerals to form ore bodies is, in the nature of the case, exceptional. It is dependent on many causes, and their action is so varied that it is impossible always to predict just where one will occur.

ORIGIN OF THE DUBUQUE ORES.

It will have been evident from the pages preceding that the Dubuque ores are believed not to have had their origin in deep-seated causes, but to have accumulated under the influence of agents active relatively near the surface. In considering the evidence upon which this belief is founded it is convenient to discuss, *a* the ultimate source of the metals, *b* the causes of the localization of ore bodies, and *c* the methods of concentration.

Ultimate source of the ores.—The limestones and dolomites of the region, even when far from any known body of mineral, and when quite barren when examined by ordinary methods of analysis, still show notable percentages of both lead and zinc when tested by the large quantity methods used by Winslow and Robertson.* In table I the results of such tests as made by Dr. J. B. Weems are given. While the percentage of the minerals is in no case large, the total amount by acre or square mile of the formation, assuming that they represent average conditions, is quite sufficient to account for the largest leads in the region.

* Missouri Geol. Surv., Vol. VII, pp. 740-742.

TABLE I—ANALYSIS OF DUBUQUE LIMESTONES AND DOLOMITES.

	Analysis No.	H_2O	Insol.	CaO	Fe_2O_3	SO_3	P_2O_5	Mgo	CO_2	Org.	Total.	Dolomite.	Limestone.	Excess CO_2	Less CO_2	PbO.	Pb.	ZnO	Zn	Rock No.
Blue rock from Halpin mine at depth of 40 ft. in Galena.	37	.06	1.55	30.23	.82	1.52	.45	19.39	45.19	1.42	100.63	88.89	5.83	.09	....	.00633	00587	.00090	.00072	304
Niagara, Cascade, Iowa	38	.26	11.34	27.19	.81	....	.60	17.78	41 46	.82	100 26	77.13	8.80	.50	...	.00567	.00525	.00020	.00016	305
Lower buff beds, Sageville, Iowa	39	.10	1.08	30.78	.90	....	.64	18.34	44.37	3.41	99.62	84.39	9.14	...	....	.00501	.00465	.....	......	306
Trenton limestone, Sageville, Iowa	40	.04	7 63	50.15	.62	....	.61	1.21	39.56	.77	100.59	7.62	86.26	...	2 96	.00611	.00567	.....	......	307
"Upper thin beds," section 33, Dubuque Tp	41	.06	5.23	28.95	1.15	....	.46	18.54	44 00	.96	99 35	83.01	7.61	.87	....	.00302	.00280	.00050	.00040	308
Niagara, Sherrill's Mound	42	.05	3.24	30.01	.74	....	.52	18.99	44.91	1.34	99 80	86.71	6.75	.45	..	.00065	.00060	.....	......	309
Galena below cap rock (1st opening) Tibey quarry	43	.05	3.33	34.56	1.26	....	.37	15.30	43 34	1.25	99.46	76.08	19.07	...	1.65	.00109	.00101	.....	......	310
Lime burning rock, Eagle Point	44	.02	2.15	30.72	.82	....	.60	19 90	45.91	.13	100.25	94.14	2.47	...	.08	.00155	.00143	.....	......	311
Non-lime burning, Eagle Point	45	04	8.63	28.86	.85	....	.51	18.82	42.08	1.07	100.86	84.13	6.92	...	1.29	.00221	.00204	.00170	.00136	?
	..	...	.....	.....	....	....	...	.....	.....	....	......	....	....	...	....	Avg.	.00326	.....	.00029	
	..	...	.....		..	...	...	...	.	....		....	....	...	...	*	00376	†	.00043	

*Avg. PbS. †Avg. ZnS.

NOTE.—1 Cu. ft. rock 170 lbs.
2,269,664 tons rock per sq. mi.
1 foot thick.
Galena—95.33 **tons per sq. mi.**
1 foot thick.
Blende—9.76 tons **per sq. mi.**
1 foot thick
Galena—19,066 tons **per sq. mi.**
200 feet thick.
Blende—1,952 tons **per sq. mi.**
200 feet thick.

These widely disseminated and minute quantities of the metals are obviously susceptible of two interpretations. In all mineral districts, even where the veins are most persistent and sharply defined, there is a greater or less tendency for the ore to spread out from the veins proper and impregnate the country rock. In a region much cut up by veins the country rock may become so thoroughly mineralized that it may itself be an ore. In the Cripple Creek district much of the ore is of this character,* and the phenomenon is so common that examples need not be multiplied. Wherever there is underground water there are chemical changes and rearrangements taking place in the rocks. No body of rock is stable and constant in composition, and in rocks, such as limestone and dolomites, which are easily soluble, the amount of change possible and commonly occurring is very great. In the presence of sulphides and water, carbonate rocks are susceptible of many changes; and in the region in question the sulphides are widely distributed, and underground water has already been shown to be an important factor.

It is clear that the action of circulating waters may be either toward dissemination or toward concentration of a particular substance, and that this action will depend upon a number of factors, including the chemical character of the substance, of the water and of the country rock, and the rate, direction, constancy and duration of flow, and the temperature and pressure of the circulating solution. A set of conditions under which ore occurring in definite veins might be conceived to have become thoroughly disseminated is so possible that doubtless much ore even in the region under discussion has been so distributed. It is not, however, believed that this is true of the bulk of the disseminated ore. In order to make such a case conclusive it would be necessary, first, to demonstrate that the vein fillings were themselves original, and were not due to lateral segregation, since the process of concentration is quite as common and easy

*Penrose: Sixteenth Ann. Rep. U. S. Geol. Surv., pt. II, pp. 145-146.

of occurrence as that of dissemination. If the vein deposits of this or any other ore district be definitely proven to have their genesis in deep-seated causes, then the probability is that any disseminated ore has been carried out from them, and in such a case it would be expected that the quantity of ore so found would regularly decrease with the distance from the vein. In any other case the burden of the proof is upon those who hold the widely disseminated and minute quantities of the metals to be wholly secondary. Against such a view there are certain objections which may be justly urged.

In the first place, it is a well established fact that minute quantities of all the common metals occur in sea water. Dr. J. R. Donn† has recently investigated this question afresh and has confirmed the other findings. If such metals occur in minute quantities in the sea it is difficult to understand why they should not be supposed to occur in minute quantities in sedimentary rocks which are formed in the sea. If calcium and magnesium, which occur in larger though still small quantities in ordinary sea water, can be deposited either by chemical or other agencies, why not lead, zinc and iron? The mere statement of the case is sufficient to show the inherent probability of its occurrence. Again, in some of the analyses quoted, and in others given by Winslow and Robertson,‡ the metals are found in rocks miles from any known or probable vein deposit. In ordinary field work nothing is more common than to find small quantities of metallic sulphides in undisturbed rocks, wholly outside known mineral regions. Such an instance is the occurrence of blende and of millerite, as reported by Keyes§ at Keokuk, and the recent finding of small quantities of blende in Van Buren county. Blende occasionally occurs in the septarian nodules of the coal measures; and the sulphide of iron is one of the most widely distributed of minerals. To assume that all of these occurrences are due to a wandering of the ore from

†Trans. Amer. Inst. Ming. Eng., Vol. XXII.
‡Missouri Geol. Surv., Vol. VII, pp. 479-482.
§Iowa Geol. Surv., Vol. I, p. 187.

some vein deposit requires better proof than has yet been given. While it may be true that it is impossible to prove the absolute originality of the metallic sulphides, except when found in the basic constituents of pyrogenetic rocks, yet something must be allowed to probability, and up to the present it would seem that the evidence may justly be interpreted to mean that, except when found in definite association with veins of known or probable deep-seated genesis, disseminated metals are probably original.

Localization of ore bodies.—Granting for the moment that the metals in the present case were originally disseminated throughout the rocks of the district when the latter were formed, it is pertinent to inquire why the ore bodies are confined to somewhat definite areas separated by apparently equally favorable but practically barren ground. This phenomenon is one which has been noted by all previous workers, and has been the chief stumbling block in the way of accepting the hypothesis that the ores originated by the general process known as lateral secretion. It is the one feature of the region not easy to explain on such a hypothesis, but it admits of ready explanation if the ores be considered as of deep seated origin.

The present distribution of the ore districts must be due to causes operating either at the time of original deposition or during the period of concentration. Either the areas now found to be ore-bearing were particularly favorable to its deposition, or by peculiarities of structure or position they have favored the concentration in them of the metals disseminated through the rocks of the surrounding area. If the ores were formed in deep seated veins and came up from below in solution or otherwise, the contrasted richness and barrenness of neighboring areas would be but the natural results of the presence or absence of fault lines deep enough to communicate with the sources of supply. If the ore be conceived to have originated through lateral secretion, fault planes, if present would still afford the most favorable situations for the

accumulation of ores as Spurr has excellently shown in his studies of the Aspen district.* Fault planes cutting across the area and extending to considerable depth, breaking up and fracturing the rock often for some distance on either side, afford excellent opportunity for the movement of water and consequent concentration and deposition of ores. Probably also the bringing into juxtaposition of two sorts of strata of diverse composition opens up the way, under the influence of water, to a considerable amount of chemical activity. It has already been shown, however, that in the Dubuque area there are no faults of any importance, and while, according to Blake, certain of the Wisconsin lodes have been influenced by faulting, the Dubuque area proper is remarkably free from faulting of any kind. The region as a whole is a notable exception to the mineral districts of the world in the absence both of igneous intrusions of any kind and of anything but the simplest structure. The great crevices which run through the region belong rather to the category of joint planes. They have doubtless influenced the flow of underground waters and have in so much determined the localization of ore bodies. They are grouped along certain low anticlinal axes, but crevices apparently quite as favorably situated are barren, and so far as present studies go this grouping parallel to the almost insignificant anticlines can not be considered to be the whole explanation. It has probably influenced, in a manner, the secondary accumulation of the ores, but there are reasons for believing that there were inequalities in the primary distribution. Whitney, recognizing the difficulties of the situation, suggested that the metallic sulphides were thrown down in particular abundance in those portions of the sea particularly charged with living forms. To this it is sufficient answer that there is no known relation in the rocks between abundance of fossils and ore. If there were the Trenton should be more mineralized than the Galena, whereas the reverse represents the facts. It is true that the evidence of

*Mon XXXI, U. S. Geol. Surv.

former life in the Galena has been to some extent obliterated, but it is doubtful whether the Galena ever was as fossiliferous as the Trenton now is, and it is certain that the Receptaculites and gastropod horizons which persist through the Galena are nowhere associated with notable ore accumulations.

The oil shale occurring at the top of the "glassrock," and commonly forming the base of the Galena, is an exception, in that it is usually fossiliferous, and at the same time is a reliable ore horizon. It has already been suggested, however, that its action may have been entirely secondary in arresting the downward flow of ore-bearing solutions, and Blake has furthermore suggested that the hydrocarbons in it may not necessarily be due to the decay of plants and animals.*

Chamberlin† has appealed to the probable ancient geography of the sea bottom and the action of various currents in the accumulation of sea weeds in particular areas, with the consequent evolution of hydric sulphide and the precipitation of metallic sulphides. This hypothesis necessarily implies a large amount of speculation, and is one difficult either to prove or disprove. It assumes a point of which we have no evidence other than the ores themselves, namely that there was a particular accumulation of hydric sulphide in these areas.

Mr. Arthur Winslow, in his explanation of the Missouri ores and by implication of those of Iowa and Wisconsin, would make the whole matter secondary and dependent upon the irregularity of processes of accumulation.

In considering the matter it seems significant to note the association here, as is common elsewhere, of the ores of lead and zinc with great bodies of dolomite. This association has been so frequently noted that it is hardly necessary to cite examples. In the region in question there are no important ore bodies except those in the dolomite, or those secondarily

*Trans. Amer. Inst. Ming. Eng., Vol. XXII, p. 629.
†Geol. Wisconsin, Vol. IV, p. 529.

derived from it. This is true as well of the ores in the Lower Magnesian or Oneota, at Lansing, and on Mineral creek in Allamakee county. The great bodies of disseminated lead ores at Mine La Motte, Bonne Terre, Doe Run, Flat river and other localities in southeastern Missouri are all in dolomitic rock. The ores of central and southwestern Missouri are in some cases in dolomite and in others are supposed by Mr. Winslow to have been secondarily derived from the decay of a series of rocks which must have been largely dolomitic. The silver-lead ores of Leadville* are in dolomite, and those at Aspen† follow the same rule. Indeed it would be easy to give a long list of such occurrences. The association has been frequently noted before but has not been considered of primary significance.

The opportunities for secondary association of the ores and dolomite are numerous. Dolomite is itself a porous rock and its homogeneity, as has already been shown, causes it to fracture in a few extensive planes rather than many of limited extent. It is therefore particularly susceptible to the changes which come from the circulation of waters through rock, and forms a ready habitat for ores. Being readily soluble, and carrying lime and magnesia, it affords quantities of these substances which may, in some instances, be important primary or secondary chemical agents in the deposition of ores. It is a rock which may readily be conceived to selectively absorb ores from a solution coming from any ultimate source. It is particularly susceptible to metasomatic replacement. These various facts have been held to be sufficient grounds for the association of dolomite with lead and zinc ores. A consideration, however, of the conditions under which dolomite is formed, offers the hypothesis that these conditions are themselves favorable for the primary deposition of metallic sulphides in minute quantity. In the particular

*Emmons. Mon. XII, U. S. Geol. Surv., p. 375.
†Spurr. Mon. XXXI, U. S. Geol. Surv., p. 206, et seq.

case in hand it has been shown that the dolomites accumulated in shallow, isolated basins, free from the incursion of fresh water, and exposed presumably to active concentration by evaporation. This concentration progressed so far that the magnesia became notably in excess and was deposited, entering into combination with the underlying, newly formed limestone, itself formed probably by ordinary means before the period of evaporation. It is clear that, in concentration by evaporation, not only would the per cent of magnesia be raised above the normal, but the same would be true of all other salts in the sea water. The lead, zinc and iron, brought down from the adjacent Archean land mass, perhaps as the soluble sulphates, would themselves be concentrated. Whatever of reducing agents were present in the water would be increased, not in quantity, but in percentage, and accordingly in effectiveness, under which conditions the reduction of the sulphates and the deposition of the sulphides in the quantity in which they are now known to be present, is certainly quite within the limits of probability.

The conditions outlined, inasmuch as the concentration was in shallow water, probably was not uniform either in time or position, and that the precipitation should have been irregular to an equal degree is quite to be expected. The irregularity, following no known law of present position or structure, and yet secondarily influenced by the latter, exactly fits the facts of the field. These secondary changes have been so numerous as somewhat to obscure the original conditions so that a series of analyses fails to show as direct a relation between the degree of dolomitization and the percentage of disseminated metals as the hypothesis suggests. The broader field studies show, however, that the most perfectly dolomitized areas, if the factors controlling concentration be favorable, are the ones which have yielded and are yielding the largest amounts of ore. While perhaps the truth of the hypothesis cannot at present be clearly demonstrated, it is believed that the facts are sufficient to warrant its acceptance

as a working hypothesis to be farther tested and perhaps changed.

In the matter of the possible derivation of the ores below, it can only be stated that no sufficient evidence has yet been advanced for a belief in such a genesis. No veins are known to run to anything more than a limited depth; the veins worked have none of the usual characteristics of the "true fissure veins." There is practically no faulting and no intrusive rock at all. The ores could not have come up from below, except in solution, and it is difficult, if not impossible, to conceive of their crossing the great aquifers of the Saint Peter and Saint Croix sandstones below without becoming diffused, and yet these rocks never show any signs of mineralization. Furthermore, if any of the ores of the district have had such a genesis it will be conceded that the sulphides occurring in vein form would probably be the ones, yet the blende so found is characteristically black through the apparent presence of organic matter, showing that it must have been deposited in the presence at least of surface agencies. These facts, with an adequate hypothesis accounting for the deposition and concentration of the ores under ordinary conditions, throw the burden of proof upon those, if any, who would appeal to what, for this region, is certainly an extraordinary hypothesis.

Concentration of the ores.—The metals, as originally precipitated, were so widely disseminated that they would never have been of value, and probably never would even have attracted attention. It is not thought that, in this district at least, there are any bodies of workable ore except as a result of local concentration. The general process of concentration or aggregation has probably been that of the oxidation of the disseminated sulphides by ground waters percolating through the rock, the transmission of them as sulphates to the crevices, and their redeposition there as sulphides by the waters reaching the cavity by a more direct route and charged with reducing agents, with the secondary reduction of the

sulphides by each other. The different crevices carried probably somewhat different solutions, and a crevice which is not itself ore-bearing may make another valuable where the two intersect. In the Stewarts cave, for example, the north crevice has not so far been found to carry much ore, but wherever there is a north-south crevice connecting it with the parallel crevice to the south, a bunch of ore has been found in the latter. The north crevice has indirect communication with the surface through the Timmons, and receives its waters after they have penetrated decaying vegetation and organic matter, while the south crevice is charged with solutions which find their way to it after a devious course through the porous rock itself.

The secondary changes which have resulted in the large change of the sulphides to oxides and carbonates have already been discussed.

The question naturally suggests itself, in view of the known presence of large amounts of artesian water in the rocks below, whether this water might not have been either the source of the ore or the precipitating agent. The following analyses of water from the level, representing the general character of the water in the mines, and from the artesian wells themselves, together with the analyses already quoted of water from the Saint Peter sandstone, negative this view. The character of the artesian water shows that it is not the same as that found in the mines, a fact confirmed by the irregular level to which the mine water rises and the constant horizon of the artesian waters. It is also apparent that the mine water is not a mixture of artesian and surface waters, nor that one would be likely to have precipitative influence more than the other. The two waters have much in common because they traversed much the same sort of rocks. The analyses quoted were made by Dr. Floyd Davis, and are given by the courtesy of Messrs. Robert and W. W. Bonson:

	PARTS PER MILLION.	
	Eagle Point (Artesian).	Level mine water.
Total solids	308.000	393.000
Nitrogen in nitrates	None	.060
Chlorin	5.750	3.875
Sulphuric anhydride	13.300	52.180
Silica and insol	113.460	13.360
Oxygen in iron and aluminous oxides	None	None
Lime CaO	82.800	108.060
Magnesia MgO	58.300	65.220
Sodium chloride	17.500	28.700
Potassium chloride	1.280	....
	GRAINS PER GALLON.	
Silica and insol	.785	.779
Potassium chloride	.075	....
Sodium chloride	.494	.372
Sodium nitrate	....	.014
Sodium sulphate	.637	1.557
Magnesium sulphate	.630	3.349
Magnesium carbonate	6.689	5.713
Calcium carbonate	8.622	11.232

The cause of deposition of ore is doubtless, in detail, the meeting place of diverse currents or flows of water, but in a broader way it is determined by the surface of permanent underground water level. Below the surface of any region is a second surface which reflects all but the minor inequalities of the overlying topography, and which is the surface of ground water. If one dig a well he normally passes through some feet of dry or moist earth but below that comes to a level at which water stands in the well. On top of a hill this level may be but little if any deeper as measured from the crest than on the hillside or on the bottom land. Very deep valleys, however, cut this level, and springs mark the horizon. Peculiarities of structure may cause the water level to be cut by relatively shallow valleys, or springs may occur well up on the side of the hill. Normally, however, the water level slopes down on approaching a stream so that the latter barely cuts it. As a result springs are apt to be at the base of the

river bluffs, and many shallow valleys do not cut the ground water level at all. It is a broad sheet underlying the rocky surface, and if at any point it be penetrated, water is secured. In wet weather this horizon rises, and in long dry seasons it sinks, and wells must be driven deeper to overtake the receding surface.

If powerful pumps be installed at any point the horizon may be lowered at that point, unless the rock be so porous that the water flows as fast as it is pumped out, an unusual condition under ordinary structural conditions, since the rate of flow through even porous rocks is very slow. The waters which fall on the earth in part are evaporated, in part run off over the surface, and in part sink down to this underground water surface. Beyond that point the movement is very slow, so slow that the waters are almost stationary, though there is none the less a constant movement through the rock to lower outlets. The waters lie there practically dormant and become charged by solution with the various salts disseminated throughout the rocks. They largely lose the oxygen and other elements with which they were charged when they started to seep through the ground, and become practically reducing agents. The surface waters constantly coming down to this horizon, having traveled with relative rapidity through a narrow zone of rock, are charged with somewhat different elements, and, at the meeting place of the two, precipitations and other chemical changes are relatively active. From time to time changes in the altitude of the land, in the amount or rate of precipitation, in the temperature or other climatic conditions, raise or lower the ground water level, and there is accordingly here a zone through which chemical action is constantly taking place.

At a still lower level there is a second zone of importance in the genesis of ores. Near the seashore, a hole dug in the sand encounters sea water at about the level of the same water in the sea; allowing for structure and other modifying conditions, the same thing holds true of a hole 1,000 miles

inland. In the latter case, however, the sea water is found a little above the sea level proper, at the level of no flow. That is, when water sinks to this level, gravity ceases to impel farther flow; they have practically reached the ocean though it was reached by going straight down. Above this level and that of the ordinary ground water there is a zone, broad or narrow as the case may be, in which the waters have a slow movement and in which they are influenced by the character of the water coming down from above. Below this zone there is no movement of water, except through structural or thermal agencies, and the amount of water received from above is so small in proportion to that constantly present, and the waters coming down here themselves become so charged with salts and robbed of oxygen in their long journey through the rocks, that there is little chemical action. Below this level of no flow, structure and heat become determining factors in the distribution of ores. Above it, structure simply modifies general conditions, and heat is rarely an important factor in the problem.

At Dubuque the sea level lies some 500 feet below the lowest known workable deposit. There are no important modifying structural conditions, and the ores are found along the general line of the underground water level. The fact that within recent geological time this level has suffered important changes holds out the hope that the zone of ore accumulations will be found to be relatively deep.

It may be well to recapitulate here the reasons for believing that the dolomitization was accomplished before the deposition of the Maquoketa, and was not a wholly secondary change due to the ordinary circulation of underground waters. In the first place the dolomitization covers large areas and considerable thicknesses. It does not show any relation to definite fractures or water channels, but is characteristic of the

whole extent of the formation. The rock is quite as completely dolomitized under cover as where exposed to the surface, and this is true even of the deeply buried portions of the formation, as Norton has shown from his studies of the artesian wells. Where dolomite has been definitely proven to be the result of changes brought about by circulating waters, it has shown definite relationship to water channels, joint planes, or other fractures and there is no such preponderating evidence in favor of such an origin for all dolomites as to throw the burden of proof upon those who would advocate another origin for any particular dolomite. Furthermore, if the change be referred to circulating water, it is incumbent to show the source of the magnesia which they must bring into the formation. A simple calculation based upon any of the analyses in the appended table will show that the amount of magnesia to be accounted for is very great indeed. The underground waters of the region in question as has already been shown, are, so far as the Galena formation is concerned, probably local in origin and in circulation. Granting the contrary, however, for the moment, and there are two possible sources; first, the Niagara, which is above, and second, the Oneota below. It is not certain that waters circulating through the rocks could be counted on to take up magnesia from the Niagara and carry it through the practically impervious Maquoketa only to redeposit it in the Galena. On the other hand, if the waters be held to have ascended it is pertinent to ask why dolomitization is limited downward everywhere by the shale with undolomitized limestone below? In either event such a solution of the problem would merely place the problem itself one step farther away and it would then be necessary to inquire as to the source of the magnesia in the Niagara and Oneota. It has been shown that there was no period of erosion between the Galena and the Maquoketa, so it is impossible to refer the change to surface waters of such a period.

The explanation suggested in the preceding pages has none of these difficulties to face and accords with all the known facts of the field. The absence of mechanical sediments in the Galena phase shows that erosion was not active, so that there were not large quantities of fresh water being poured into the sea to dilute it. The mere presence of the limestone shows that none the less deposition was taking place and there is reason to believe that this was shallow water deposition. The hypothesis of the change of the newly formed calcareous deposits to calcareo-magnesian deposits under the influence of overlying bodies of concentrated sea water accords perfectly with the known facts of the field and is not in discord with any. This with the inability of any other recognized process to explain the facts, has been the reason for its adoption.

PRACTICAL CONSIDERATIONS.

MINING TITLES.

Mining titles in the Dubuque region are, to some extent, clouded with the same uncertainties which are characteristic of titles in all new mining regions. The land has all been sold by the government and is held for residence or agricultural purposes. In general the mines are not worked by the land owners, but by lessees. In the past the leases have been largely oral agreements made in the presence of a witness, and were unlimited as to time. The rights of the lessee continued so long as the work is carried on in a "diligent and miner-like manner." In the absence of a clear definition of what "a diligent and miner-like manner" meant the courts have relied upon local custom, and this has been so uncertain that practically it has been a very difficult thing to dispossess a lessee so long as he left tools of any kind upon the ground. The net result is that many excellent leads are tied up in the hands of men who are not prepared to work them themselves, and who will not let others work them. The land owner, unless he has been exceptionally careful, is helpless,

and in the absence of statute law the court decisions applicable are so few that rights are very poorly defined.

The exception is in the case of the land of the Bonson estate, or land leased under the Bonson rules. These rules, which were drawn up many years ago, cover many of the leases, and are given below:

RULES FOR THE GOVERNMENT OF LESSEES OF MINERAL LANDS OWNED BY THE BONSON ESTATE.

1st. Persons entering upon said lands to mine without the consent of the owner thereof, acquire no right therein by virtue of such entry.

2nd. Said lands are leased only by the range or crevice, and are to be worked regularly, continuously, and without cessation unless permission to the contrary be given by the owner thereof.

3rd. Lessees are not allowed to sell, convey or relet their working right in said lands without written consent of the owner thereof.

4th. Lessees are not allowed to remove, for the purpose of sale or otherwise, any mineral by them raised from off the ground by them occupied.

5th. Lessees shall sell no mineral by them raised to any person or persons without first notifying the lessor of such intended sale that he may be on the ground to protect his rights therein and collect his rent therefor.

6th. The lessee shall pay as rent to the lessor the one-sixth part of all mineral raised or mined from off the leased premises.

7th. A failure upon the part of any lessee or lessees to carry out any or all of the foregoing rules, shall work a forfeiture of all rights acquired in said lands, and the lessor shall have the right, without notice, to enter and take possession of the same; said lessee or lessees by their failure release any and all claims of whatsoever nature in and to the leased premises.

According to the sixth rule the royalty is fixed at one-sixth of all mineral, but mineral here is interpreted to mean lead ores only. At the time the rules were drawn up zinc was not mined. The customary royalty for zinc is 10 per cent. Since the introduction of concentrating works there is usually a provision that the cost of concentration shall be deducted before the royalty is paid.

METHODS OF WORK.

Up to 1899 there was not an incorporated company interested in the Dubuque mines. Up to the present the universal method of work had been by partnership. The mines are held as individual interests, and a system of Saturday night payments prevails. If ore has been sold, the proceeds are divided according to the various holdings. If no

ore has been sold, an assessment is made to cover the deficit. The mines are small, but few men are employed, and usually the owners, or rather lease-holders, have little invested or to invest. Under such a system of working very little dead work is possible, as a mine which does not yield is simply dropped. It is impossible to enlist capital in an enterprise when the control is in the hands of men of no technical knowledge or skill, and of such slight business experience as in the case of most of the miners of the region. This, and the insecurity of titles mentioned above, have been the chief retarding influences. With such methods of business it is not surprising that ore has been poorly cleaned, has brought low prices, and that no serious attempt has been made to pump the mines so as to get at the lower ore horizons.

The system of working single crevices and depending upon single bunches of mineral to make a mine a success, must be abandoned if more money is to be invested in the region. The uncertainty of finding chimneys, and the large proportion of narrow work to stoping, make some modification of ordinary lode mining desirable. On the other hand the concentration of the ores along the crevices and at certain levels indicate that the methods of opening wide stopes followed in working the disseminated ores of southeastern Missouri, can not be followed entirely. It seems probable that the most successful mines will be located where crevices are known to be numerous and close together. The ground may then be worked as a whole by means of a deep pump shaft on the most favorably situated crevice, preferably near the center of the tract, and cross cuts driven along favoring north-south crevices at the level of some one of the various openings. Each main crevice can then be opened up by proper levels and uprises. Some of the area can be drained to advantage by levels driven in along certain well known crevices, but for reaching the lower horizons in much of the area, pumping will be necessary.

In the matter of pumping, little that is definite can now be stated. It is always difficult to judge the amount of water that must be handled in any mining operation, but in the present case there is no reason to believe the amount is excessive. Practically all the mining will be done above the level of the Mississippi, that is above the controlling water level of the region. There is no reason to believe that the mine waters are connected with the artesian aquifers below, as has already been shown. The presence of so much open ground, and the local difference in water level, indicate that the water is the ordinary underground supply, and, in a country so much cut up by streams and valleys as this, there is no reason to believe that the pumping will be more difficult than in other regions where water is now successfully handled.

PROSPECTING.

In seeking new country for development there is no better method than that of tracing out the known crevices. These have been so well opened up in the search for lead deposits that the general course is, in many cases, already known. The crevices are so definite in direction that it is quite feasible to survey ahead along the course of a well known crevice, and accurately locate a shaft upon it. Intersections are, of course, favorable points, and when two crevices can be traced to a crossing it is usually a good point to begin operations. Since the "openings," in so many cases, are actually open so that an explorer may crawl along them, and in other cases are filled with dirt carrying enough to pay for its removal, this is an exceptionally favorable region for prospecting by means of open shafts. The shafts of the region are small, ordinarily 3x5 feet in cross section, and are cheap, costing from $300 to $600. A single shaft may give access to a mile or more of underground openings. In such a case the shaft is pre-eminently the cheapest method of exploration. In many instances old shafts may be cleaned out at a cost of

from 80 cents to $1.50 a foot in depth, in which case the exploration is even cheaper.

The fact that ore is distributed so irregularly along the crevices, a really valuable bunch of mineral occupying often a very small space, makes the drill less useful than it would be in locating disseminated deposits. Drilling has been very little attempted, and core drills have not been used in the region at all. It would be possible, of course, very quickly to settle by their use the question whether "flats" of value are to be found in the region, but they probably could not settle much of anything else. The question of flats will, in time, be settled in the course of ordinary mining operations in any event.

Recently power hoists and air drills have been introduced, pumps are being installed, and certain of the mines are being more systematically worked.

COMPOSITION AND TREATMENT OF ORES.

There are four general classes of ores at Dubuque, though these classes grade into each other to a greater or less extent. They are *a* lead ores, *b* dry bone ores, *c* mixed bone and jack ores, and *d* jack and pyritiferous jack ores. The lead, very rarely, occurs in any considerable amount so closely associated with zinc ore as to need to be separated by milling. Most of the lead is very pure and only needs to be washed free from the sand to be ready for charging in the furnace. In the general movement downard of the ores the lead has been concentrated in the upper and more weathered portions of the rock, which accounts for its relative freedom from impurity. It is a soft lead of nearly theoretical purity, specimens from the Karrick mine running 86.43 per cent Pb. It does not contain silver in more than a trace, though certain of the Illinois ores are said to yield enough silver to influence the price of the ore.

When lead occurs mixed with the other ores, as at the Ahern mine of the Dubuque Lead Mining company, where it, together with marcasite, filled solution cavities in a blue dolomite,

and at the Pike's Peak mines where a certain amount of lead is found in intimate relations with the blende and marcasite, it is easily milled out owing to its greater specific gravity. This runs from 7.4 to 7.6, and in all milling operations the galena comes down on the screens of the first jig. Very little lead ore has, however, been jigged at Dubuque. It is generally washed with a log washer only.

The dry bone ores proper occur, as does the lead, in the upper weathered portions of the formation. They are usually hand sorted, washed with log washers, and hand picked. To a limited extent they are now being milled, and a considerable portion of the ore of the region can be marketed. Dry bone assumes a wide variety of forms from a clear translucent stalactitic variety, through honeycomb bone, to rock bone. Analyses of the ore from the Timber range or Ewing diggings have already been given. Assays of samples from the Cripple Creek mine gave 47.30 per cent Zn with 2.10 per cent Fe. The iron occurs as an oxide in the form of ocher or ocherous clay mixed with the ore. In washing the ore practically all the iron is gotten rid of.

The mixed bone and jack ores occur at and about water level. At present they are the ones most actively mined. Samples from the Alpine mine show 21.77 per cent, 21.6 per cent, 14.3 per cent of zinc with 9.88 per cent and 16.5 per cent of iron respectively in the last two samples. The iron here occurs in part as the sulphide and in part as the oxide. In milling it is impossible to separate the sulphide completely. In certain tested concentrates showing 47 per cent and 39 per cent of Zn respectively, 22 per cent and 19 per cent were in the form of the carbonate. By hand jigging a jack product showing 60.68 per cent metallic zinc, and a low grade dry bone showing 20.54 of zinc, were made. The proportion of jack to dry bone varies considerably in different mines, at different depths, and in different workings in the same mines. In much of the ore now being mined the bone and jack are in ratios of 3:1 to 4:1. The proportion of ore of all kinds to rock also

varies considerably. Very little dead work has been done here, and the per cent of rock moved has been very small. The Alpine mine has been worked on about as extended a scale as any recent mine, and in the per cent of ore has run down as low as 12 per cent while cutting through bars. A mill run of ore from the Fourteenth street mine showed a trifle less than 16 per cent. The Bush and Langworthy ores run higher, but in neither case is any large ground opened up.

In milling these mixed ores it is impossible to make a complete separation of the bone and jack. Pure dry bone has a specific gravity of 4.30 to 4.45; pure blende runs from 3.9 to 4.1 In this field, however, much of the dry bone ore is really dolomite impregnated with zinc oxide. As a result there are all degrees from a dry bone heavier than blende to one lighter, and there must always be an important amount of middlings of mixed bone and blende. Such mixed ores are of lower value. On the one hand they are of lower value to the oxide manufacturer because the sulphur in the blende makes a sulphate in the oxide. The spelter manufacturer on the other hand loses a certain amount of the light bone in roasting the sulphur off the blende, since zinc volatilizes very easily.

The blende and blende-marcasite ores occur below water level, and are manifestly the ones which will be most mined in the future. The blende itself is an excellent smelting ore and quite free from iron. Its dark color appears to be due to organic matter and disappears at low heat. A selected sample of jack from the Rabbit Hollow mine showed 63.98 per cent zinc, with 42 per cent iron. Much of the ore, however, occurs with marcasite. Indeed it is usually true that between the dolomite and the blende there is at least a thin band of the iron sulphide. The iron sulphide seems to have caused the precipitation of the blende from the sulphate, with the consequent oxidation of the iron because of the weaker affinity of zinc for sulphur, as suggested by Van Hise. In milling it is quite difficult to separate the iron and zinc sulphides. Ordinary jigging is only partially successful. By

roasting very slightly the iron sulphide can be made to swell up so as to be lighter than the blende, after which it can be jigged out as described by Blake.* By roasting heavily enough to drive the sulphur from both minerals it is also possible to use a magnetic separator. It is also possible to make a working separation by fine grinding and the use of concentrating tables, the Wilfly, Bartlett & Smith being seemingly best adapted to this particular class of ores.

While it is to be expected that, as more attention is paid to the district, better milling methods will be introduced, it is an open question whether the blende-marcasite ores can be in all cases successfully milled, and that fact is the most discouraging feature in the prospects for the district. At present the smelter, particularly where he makes sulphuric acid as a by-product, can do more than the mill man towards utilizing the ores.

The only mill now operating at Dubuque is a custom mill owned by the Dubuque Ore Concentrating Co. This mill has a capacity of from fifty to eighty tons in ten hours, depending on the character of the ores. The ores are run first through a 9x15 Blake crusher, then through 14x20 rolls, are elevated and sized by means of a trommel screen with one-half inch round holes. The over size from the screen goes to a second pair of rolls and back to the elevator. The undersize goes to a five-cell Cooley "rougher" jig, with 26x36 plungers, and 24x36 inch screens, which are grates with three-sixteenths inch holes. The eccentrics are driven at 140 revolutions per minute and have a stroke of $\frac{3}{8}$ to $\frac{3}{4}$ inch. The tailings here are hoisted and laundered away. The middlings are drawn and re-ground in a third set of rolls. This re-ground material, with the fine material passing through the screens, is re-elevated and run over a second, six-cell, "cleaner" jig, with plungers and screens 24x36 inches. The screens are 4, 6 and 8 mesh. The eccentrics of the first three plungers make 200

*Trans. Amer. Inst. Min. Eng.

revolutions per minute. The last three are driven 225 revolutions per minute. This plant uses about 400 gallons of water per minute, a part being caught in a pond and run through in a circuit. The power for such a plant is properly about forty-

FIG. 95. Concentrating mill for lead and zinc ores. Dubuque Ore Concentrating Co., Dubuque, Iowa.

five horse power. In the Dubuque plant the engine and boilers are considerably in excess of this. In running, two men are required in the jig room, one in the engine room, and from two to three in the crusher.

SMELTING.

While both lead and zinc ores are mined in the Dubuque region, and iron has been mined within a few miles of the city, lead is the only mineral which has been smelted. The zinc ores are shipped to Mineral Point, Wis., and the various furnaces in Illinois and Indiana, and the iron, which was formerly shipped to some extent to Chicago, is not now

worked. The reason for this lies mainly in the fact that it is possible to effect a good saving of lead by means of a furnace which requires but a very small investment, and which is accordingly within the reach of the local capitalists. Zinc, on the other hand, requires a considerable investment if the valuable by-products obtained in smelting the sulphide ore are to be saved. When fuel must be shipped in, it is rarely advisable to attempt zinc smelting, except with a modern and thoroughly efficient plant. The old and common process of spelter making with hand-rake reverberatory furnace for driving off the sulphur, and with coal-fired Belgian retorts for saving the metal, is not to be recommended except where coal is abundant and cheap, and even then the wasting of the sulphur entails a heavy loss. It is significant that in the Weir City, Pittsburg region, where so much of the Joplin ore has been smelted, these furnaces are being dismantled, while new ones are being erected in the natural gas region of Kansas. The building up of an important spelter industry in Indiana is indicative of the same conditions, and is but another instance of the well established rule that, in general, ores go to the fuel rather than the reverse. At La Salle and Peru, Ill., by means of finely equipped and excellently managed plants, it is possible to use coal as a fuel; but even here it is not used for direct firing, but is merely the source or producer of gas which, in an ingeniously devised furnace, is burned with very considerable efficiency.

The question as to the possibility of manufacturing spelter at a profit at Dubuque has not heretofore arisen for the reason that the blende has not been extensively mined. Very considerable bodies are, however, now being opened up, and the indications are that important blende mines will be a feature of the region from now on. With the opening of these mines and assurance of a considerable and steady supply of jack, the question of local spelter manufacture is bound to come up for consideration. There are now considerable bodies of blende open across the river in Wisconsin, and it is

not impossible that, in the event of a local furnace being installed, these could be drawn upon to supply any deficiency of ore. Both Illinois and Iowa coals come into the Dubuque market, though the former commands most of the trade. Steam coal can be purchased there in car load lots at an average yearly price of $1.50 per ton in ordinary seasons, though now it is higher. The freight out on ore is now $1.50 a ton and upwards. These figures are sufficient to indicate that with a proper supply of ore assured, and a modern gas-burning furnace with arrangements for the saving of sulphuric acid, local spelter making is a potentiality of the future.

The zinc ores so far mined have been almost exclusively the carbonate. In the earlier days they were to some extent used for the manufacture of spelter, but are now exclusively made into oxide, to which they are particularly well adapted. The ores go to the Mineral Point Zinc company which has, at Mineral Point, Wis., the most important oxide plant in the west. The first attempt to smelt the zinc ores of the Upper Mississippi region was made by the Mattheison and Hegler company at La Salle, Ill., in 1852. Later the manufacture of oxide was taken up at Mineral Point under the direction of a certain Mr. George and Messrs. Jones Brothers, who visited Wales and spent sometime in the works there, learning the business. The company, after an uncertain and precarious existence of some years, is said to have formed a connection with the New Jersey Zinc company, and of recent years has been very successful. The original plant has been from time to time enlarged, and within the present season sulphuric acid works have been added. Forty thousand tons of zinc ore can now be handled per annum.

Zinc oxide is used as a base for white paint as a substitute for white lead. Its virtues are to some extent in dispute, white lead manufacturers declaring it a simple adulterant, but oxide burners and many painters stoutly maintain that it has a value of its own. It is claimed that it covers more surface than white lead in the ratio of 10:13, is not affected by

sulphurous gases in the air and is not injurious to workmen. However that may be, it is largely used, 32,747 tons being manufactured and sold in 1898 with a value of $2,226,796. Oxide is preferably made from the carbonate ores for the reason that it is important that it should be free from all traces of sulphur. Mixed ores can be used to a limited extent and there is a certain market for oxide carrying not to exceed 4 per cent of sulphate. It is, however, better economy to use the sulphide ore for the manufacture of spelter and sulphuric acid and to depend upon the carbonate or "bone" for oxide.

Smithsonite or carbonate of zinc contains, when pure, one molecule of carbon dioxide and one of zinc oxide, or 35.19 per cent CO_2 and 64.81 per cent ZnO. In smelting it is necessary to get rid of the carbon dioxide. In order to do this it is necessary to heat the ore to almost 1,400° F., at which temperature the metallic zinc is reduced and volatilized, after which it is allowed to cool in the presence of an excess of oxygen, under which circumstances it is oxidized. In accomplishing this in American practice the ore is first crushed and cleaned if necessary, then mixed in about equal portions with anthracite coal in small sizes. Practically at the western works screenings from the city markets are used. This mixture of coal and ore is burned in a closed furnace over a plate grate punctured by small round holes which admit a powerful blast, but do not allow the particles of fuel and ore to drop through. The blast carries the metal and some unburned fuel over from the furnace into large fire brick settling rooms where all unburned particles settle to the floor and some of the zinc condenses, though the object is to make the condensation as little as possible. These rooms are subject to a periodical clean up when the settlings are reburned in the furnace. These rooms also secure a more thorough oxidation of the metals, as fresh air is admitted here. From the settling room a blast takes the vapors through a long iron cylinder designed to allow them to cool and to secure a thorough mixture of the air and the metal.

This cylinder or pipe leads to the bag room, an ingenious arrangement for saving the oxide. By means of suitable pipes and connections the blast carrying the oxide is turned into long canvas bags suspended bottom side up from the ceiling of the bag room. The air and gases, of course, find their way out through the meshes of the cloth, the cloth serving to catch the particles of oxide. The bags are in long parallel rows; at suitable intervals the blast is turned from one row into another, and the oxide is shaken loose from the bags. Beyond this point the process is the familiar one of barreling and marking.

The process is continuous and the works are only shut down for repairs or for lack of ore. It is, accordingly, necessary to carry a considerable stock of ore on hand. The plant is necessarily somewhat extensive and is expensive because of the large amount of fire brick used in its construction. Only the best and cleanest of fuel can be used, and this forms an important element in the cost of the plant. None the less it is believed that the industry has been, for some years, a well paying one.

The galena mined near Dubuque has always been smelted principally by local furnaces. A certain amount from counties north of Dubuque has been sold to the smelters at Aurora and Chicago, where it is usually in demand for mixing with the gold-silver ores of the west. Occasionally some of the galena has gone to the local furnaces of Illinois and Wisconsin.

The first attempt at smelting ore in the upper Mississippi region was made by Julien Dubuque, who, in 1788, opened up the mines where the city named after him now stands. He erected several furnaces in the region, and up to a recent time their sites were well marked. After his death the Indians destroyed his buildings, and, as far as possible, eradicated all signs of his occupation of the territory. The Dubuque mines were then for some years worked by the Indians themselves, who bartered the ore to a group of traders who had erected a furnace on one of the islands in the

Mississippi. In 1833 the country was opened to settlement, and since then smelting has been a regular occupation.

The pioneer furnaces of the region, and probably those used by Dubuque, were simple stone platforms approximately fifteen feet square, sloping toward the center. Upon these platforms layers of wood and ore were placed alternately and the whole was fired. From time to time more wood was added and the lead drawn off from the central well. The process was very wasteful, in that large quantities of wood were used and there was a very rich slag. Much of this old slag has since been gathered up and resmelted.

After some years a type of cupola furnace was introduced, and in 1834 Peter Lormier built the first in Iowa, locating it near the mouth of Catfish creek. Within the next two years two more were built, one on the Little Maquoketa and the other in the town of Dubuque. These furnaces are said to have saved from 65 to 70 per cent of the metal, but with the introduction of the Scotch hearth they passed out of use. It is said that the first Scotch hearth built in America was erected in 1835 about half way between Mineral Point and Dubuque. If this was really the first, Iowa can claim the second, as one was erected the next year near the southern limits of Dubuque. This furnace was later removed to just above Rockdale and re-erected on Catfish creek. It has played an important part in the mining history of the county, and is to-day still in operation, being operated by Mr. J. W. Waters, a grandson of the original owner. There were for a time two other furnaces in operation, Brunskill's, located near Center Grove, and Simpson's, northeast of Dubuque. For some years, however, the Waters furnace has been the only one in operation.

The Scotch hearth is a very simple and efficient furnace. Its general character, as used in the Dubuque region, is shown in figure 96. It consists essentially of a well in which the

Plate XI. Waters furnace, Rockdale.

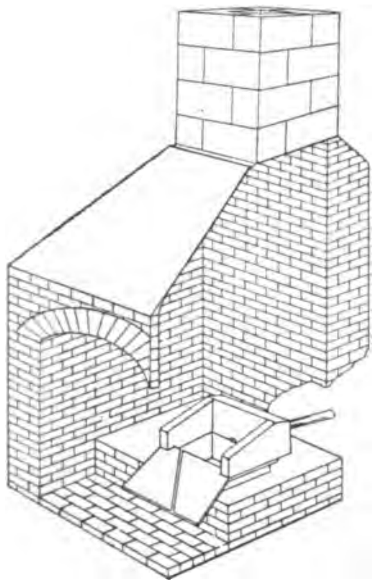


Fig. 96. Scotch hearth furnace as used at Dubuque.

metal is melted by means of a blast introduced from the rear. Ore and fuel are fed alternately, and the molten metal runs down over an apron into a mould. The box, or well, is 14 inches deep and 20x26 in area. It is made of cast iron 2½ inches thick. This casting lasts twelve to fourteen years, and costs about $100. In improved forms it is hollow and cold water circulates through it, but here the solid casting is used and seems to answer the purpose. The blast is furnished by a blower now driven by an eight horse power engine, but it was formerly driven by water power. The smoke and fumes pass up through the over-hanging chimney.

A second hearth of a similar construction is used for re-running the slag from the first furnace. In running it coke is used, and the lead produced is slightly harder. The two hearths are run alternately, running sixteen hours and resting eight. About 1,700 pounds are run per day in each furnace. There are three shifts of men, each working eight hours, and they are paid by the number of pigs produced. Wood is used for fuel, and one-half cord is needed to reduce 300 pounds of ore, with two men and eight hours work. The hearth saves about 72 per cent of the lead. The fumes were formerly allowed to pass out of the chimney as waste, but the present manager has erected an ingenious arrangement for recovering them. They pass into a horizontal, sheet-iron cylinder, three feet in diameter and 100 feet long, and from that the smoke goes out of a second chimney twenty feet high. The lead settles in the horizontal pipe and the second chimney as fine dust, and is collected and re-run with the slag.

This gives a practically complete recovery of the metal in the ore.

In starting up the hearth after it has cooled, a fire is built on top and under the well. When the metal is melted, the blast is started and new ore and fuel are fed in. These, of course,

Fig. 97. Waters' lead furnace at Dubuque showing fume saving arrangement.

float on the surface of the molten metal, which in turn runs down into the mould. The metal is run in pigs of about seventy-two pounds weight, which are marketed locally, and in Chicago and St. Louis. The old furnace is shown in plate XI and the new fume saving arrangement is seen in figure 97.

The Scotch hearth lead furnace is an interesting example of the fact that in certain cases simple old fashioned processes are best adapted to local conditions. As the Waters furnace is now run, a more perfect saving is effected at less cost than would be possible in the most improved and modern high cost furnace. Yet the whole plant, including building and ore sheds could probably be duplicated for less than

$1,000. Where large capacity is, however, desired and a continuous supply of ore can be assured the cupola furnace is probably the better adapted to the work.

In conclusion the following analyses of slag after the first and second runs are interesting:

SLAG ANALYSES.

	First slag.	Second slag.
Moisture	.17	.05
Silica and insol	4.92	27.68
Ferric oxide Fe_2O_3	18.47	*29.60
Aluminium oxide Al_2O_3	11.86	7.04
Phosphoric pentoxid P_2O_5	1.52	.78
Manganese oxide MnO	2.49	1.94
Calcium oxide CaO	16.85	15.35
Magnesian oxide MgO	8.61	7.71
Sulphur trioxide SO_3	3.22	.37
Zinc sulphide ZnS	4.44	.. ....
Lead sulphide	23.37	....
Lead (as metallic lead and as oxides)	4.48	9.48
Ferrous sulphide	......	29.60
	100.00	100.00

*As Fe_2O_3, FeO and Fe.

IRON.

In practically all the zinc and lead mines at Dubuque more or less ocher, or rust as it is familiarly called, occurs in the upper levels. In the lower levels a large amount of pyrites of iron occurs with the galena and blende. So important is the amount of pyrite that it is regularly shipped from certain of the Wisconsin mines. So far no attempt to dispose of it has been made in Iowa. The pyrite is an undesirable constituent in zinc ores, as both the iron and the sulphur must be taken out in the process of spelter making. It is not easily separated from the blende by any jigging, and serves in general to bring down the price of the zinc ore. If pyrite be found at any point sufficiently pure to be readily mined alone, it will of course prove valuable, as there is a ready sale for it to sulphuric acid manufactures.

The ocher found in the upper levels bears the same relation to the pyrite below that the dry bone does to the blende; that

is, it is the oxidized or weathered equivalent of the pyrite. In the process of weathering the sulphur has disappeared, and the iron exists as an oxide, mixed with certain earthy materials, principally silica, resulting from the decay of the accompanying dolomite.

The normal unweathered dolomite of the region, the blue rock, contains from 1.5 per cent to 2.5 per cent of silica, with about .85 per cent of iron oxide and about 1.5 per cent of organic matter and water. In the brown or partially weathered rock these constituents assume the proportions 3.5 per cent to 5.5 per cent of silica and 1 per cent to 1.5 per cent of iron, while the organic matter is not notably increased. In the iron ores the silica remains about the same, the iron oxide runs up to 48 to 65 per cent and the organic matter and water increases to from 12 to 20 per cent. The change which has taken place is, in addition to the probable carbonization of the disseminated sulphide, the ordinary one of leaching out the soluble, and leaving the insoluble matter; and the large amount of organic matter and moisture found in the resulting ore indicates that the change has been accomplished by surface waters. It is the same change which results in the accumulation of cherts and the red sticky clay known as geest, in limestone countries long exposed to erosion. In the case of the iron ores, where the large bodies, as in this region, are surface deposits, or occur in caves or crevices directly open to surface, the action is plainly one of simple residual accumulation, and the ore may have been originally disseminated throughout any or all of the formations which formerly spread over the county and which have been cut out by the erosion. In the case of the zinc ores it has already been shown that the relations to the Galena limestone are probably closer.

While ocher occurs in practically all of the crevices of the region, and surface bodies of limonite are reported from several points, only one important body of ore has been developed. In the Levens crevice there is a large amount of

ocher which would apparently be valuable for mineral paint, but which has not been exploited. The ore which has so far been marketed has come from the Larkum range near Durango. It occurs in an important east-west mineral crevice, and it was at first proposed to use the material for mineral paint. In the course of tests made in this connection it was recognized as a valuable iron ore, and a company, The Limonite Ore company, was organized to develop the property.

The officers of the company are Mr. W. S. Spangler of Chicago, president, and George S. Finney of the same place, secretary and treasurer. The company owns seven acres of land and has leases on 160 acres adjacent, the whole covering the mineral rights on the Durango iron mine. The mine is on the Chicago Great Western railway about a mile southwest of Durango on the Burton land, and includes a tunnel or drift 5x7 in cross sections along the vein some 1,200 feet. The ore can be dumped from the mouth of the drift directly into railway cars below. A certain amount of ore was mined in this tunnel by overhead stoping, but the main body lies a few hundred feet beyond the face and is as yet untouched. It can be reached through an old shaft 110 feet deep, sunk for lead ore; but during the course of the present survey there has been no opportunity to explore these old workings. They have, however, been examined by experts employed by the Illinois Steel company, and upon their report an offer was at one time made for the property. In 1896–97 about 250 tons of ore were shipped to the lake furnaces and used in furnace mixtures. The mine is 175 miles west of Chicago on a direct railway line, and the character of the ore is such as to make it fit for foundry iron as well as for ordinary furnace mixtures. It is open and porous and smelts easily. Its chemical composition is shown in the table of analyses given below and furnished by the company. In the absence of an opportunity to collect independently average samples, the

survey has made no new tests of the ore. The analyses submitted are believed to be representative.

ANALYSES DURANGO IRON ORE.

	I.	II.	III.	IV.	V.	VI.	VII.
Fe	44.55	54.80	52.66	48.43	57.66	54.74	54.74
P	.247	.056	.142	.167		1.49	.249
SiO_2	7.25	6.04	5.25	5.99		4.50	4.50
H_2O	27.72	.88	14.00			13.65	
Losonig		12.21					13.65
Al_2O_3 and Ti		.62	1.08			.88	.88
CaO		.55	.08				
MgO		.15		.68			
S		.06					
MnO			.88				
ZnO							.99

I. Illinois Steel company, analysis of four car lot, north works.
II. Washburn, Moen & Company.
III. Calumet Furnace company.
IV. Dickman & McKenzie.
V. Same, sample from east side of main shaft.
VI. Illinois Steel company.
VII. Illinois Steel company.

The value of an ore of any kind depends as much upon the cost of mining and the opportunity for smelting it as upon its character. It is difficult to give any estimate of the cost of mining in the present case, but apparently it would not be excessive. At present any ore mined would need to go to the lake furnaces, but the question of a local blast furnace is now being investigated. In addition to the Durango ores, such a furnace could draw supplies from the very large and easily mined limonite deposits now being opened up in Allamakee county. There is a good local market for pig iron, excellent transportation facilities both by rail and river, and a suitable dolomite for flux found in unlimited quantities. Below will be found analyses of the Allamakee ore and of the Dubuque dolomite:

ANALYSES: J. B. WEEMS, CHEMIST.

	Waukon iron.	Dubuque dolomite.
Water and loss	12.34	.15
Silica and insol.	9.08	2.15
Iron oxide, Fe_2O_3	68.40	.82
Alumina, Al_2O_3	6.08	....
Manganese, MnO	.90	....
Phosphorus pentoxide, P_2O_5	.41	.60
Phosphorus	.18	....
Sulphur	.91	....
Sulphur trioxide, SO_3	.40	....
Undetermined	1.48	....
Lime, CaO	....	30.72
Magnesia, MgO	....	19.90
Carbon dioxide, CO_2	....	45.91
Total	100.00	100.25

LIME.

Dubuque is one of the most important lime-producing counties in the state. In 1898 it ranked third with a production valued at about $10,000 at the kilns. In former years the amount produced was much greater, but the recent increased use of Portland and natural cement has seriously affected the lime trade. There must always remain, however, a large amount of work for which good lime mortar is the best material. In work below water level it is, of course, necessary to use cements, but in walls exposed to the air, unless exceptional strength be required, a well made and well laid lime mortar is quite sufficient and must always be cheaper because of the simpler process by which it is manufactured.

There are two lime plants in Dubuque proper, the Eagle Point Lime works and the Key City Lime works. In White Water township there is a small intermittent kiln which at intervals burns a little lime.

The Eagle Point plant is large and well equipped. It is well located both as regards material and transportation, being at the point of the bluff where the river and the C., M. & St. P. railway are both available. The quarry face shows a thickness of about forty feet of rock which is used, the base being

about fifty feet above the top of the Trenton. The detailed section at this point has already been given. The rock is a dolomite of sugary texture, massive and quite pure. The analysis shows 94.14 per cent of dolomite, the other constituents being as given below:

ANALYSES OF EAGLE POINT LIME ROCK. J. B. WEEMS, ANALYST.

	Lime-burning.	Non-lime-burning.
Water	.02	.04
Insol.	2.15	8.63
CaO	30.72	28.86
Fe_2O_3	.82	.85
P_2O_5	.60	.57
MgO	19.90	18.82
CO_2	45.91	42.08
Organic	.13	1.07
Total	100.25	100.86

In connection with the analysis of the lime-burning rock an analysis is given of a non-lime-burning dolomite, which occurs in the quarry with a thickness of twenty-one feet. This rock does not make lime by ordinary methods, and the analysis shows that the high percentage of silica and alumina are the probable cause, the rock showing only 84.13 per cent of dolomite. The presence of the constituents indicate, however, that the rock might be used for natural cement, and certain tests made upon it by Professor Simms of the State University confirm this opinion.

In working the quarry the rock is blasted down, broken with sledges to pieces not more than six to eight inches in diameter, put in tram cars with drop bottoms, and run out over the kilns, whose tops are even with the quarry floor. These kilns are two in number, are continuous and are fifty-six feet deep. They are built of Galena limestone, the upper sixteen feet being 8x10 in cross-section, and the lower forty feet being oval, with a cross-section 6x7 feet. They are emptied by drop bottoms, and are fired by two fire boxes each, built

into the sides of the kilns about six feet above their base. These boxes are five feet deep and are arranged to burn wood. It requires about four cords to burn 100 barrels of lime. The rock is burned in about sixteen hours, and the process is continuous, lime being drawn every six hours.

The lime is gray in color, almost as dark, in fact, as a cement. It slacks quickly with the usual swelling and evolu-

Fig. 98. Cliff of Galena limestone at Eagle Point Lime Works.

tion of heat. When slacked it is fairly white, but in use it makes a dark mortar. In making mortar ⅞ yards of river sand are used to one barrel of lime. The barrels are supposed to contain 200 pounds, but are not weighed and they vary somewhat. In practice much of the lime is loaded loose into cars and shipped to large contractors in bulk.

Eagle Point lime is widely and favorably known. As is true of magnesian limes in general, it forms a very hard bond and makes a mortar which improves steadily with age to an undetermined point. The capacity of the plant is 120 barrels per day with each kiln. When running one kiln three men are needed in the quarry, with one fireman and one cooper. When both kilns are in use the force is increased.

The Key City Lime works on Eagle Point avenue use the rock immediately above the flint beds, about twenty feet of the section being taken. The trade is mainly local. The lime is burned with wood in three twenty-five foot kilns, drawing every five hours. These kilns have a capacity of thirty-five to forty barrels per day.

CLAYS.

The county contains a large amount of excellent clay suitable for manufacture into brick and other products. Nevertheless the clay industry is not a flourishing one, and both in variety and in quality the district is far behind its proper position. Excellent clays are widespread, and there are three formations from which they may be obtained. These are the Maquoketa shale, the loess and the alluvium. At present only the alluvium and loess are utilized. The abundance of good building rock and the prominence of the lumber industry have been, to some extent, responsible for this fact; but an important factor has been the presence at Dubuque of several hand yards using alluvium, burning with wood and manufacturing cheaply. Without the incentive of reducing costs or necessity from the nature of the clay for better appliances in order to make brick at all, there has been no sufficient motive for the introduction of machinery and consequent improvement in the quality of the output.

The brick now made are manufactured almost entirely by hand. They are sun dried and burned in ordinary cased kilns with wood at temperatures of about 1,925° F. In burning to an ordinary red brick, there is a shrinkage of about 12 per cent, of which more than one-half is in drying. In very hard burned brick the shrinkage amounts to as much as 15 or 20 per cent. The loess used at Dubuque is a sandy waterlaid type occurring at low levels. The high level loess, and the typical loess occurring along the Iowan border in the western portion of the county, have not been used. Loess of good

character occurs within the limits of Dubuque city, and excellent dry press test brick have been made from it. It would seem that the conditions were favorable for a plant of this type, since there is good material, cheap fuel, easy transportation and an important local market. An attempt was made some few years since to introduce machinery and manufacture a high grade brick. This attempt proved a failure for business reasons rather than the nature of the material. It is rather surprising that nothing has been done in this line, since as early as 1857* repressed brick were manufactured here and used in the U. S. marine hospital at Galena. This repress was brought out from Philadelphia and was apparently one of the first used in the west.

For anything other than building brick it will be necessary to go to the Maquoketa shale for material. This formation is capable of yielding unlimited quantities of excellent material. From seventy to 150 feet of the section consists of soft very plastic clay. This forms the main portion of the Upper Maquoketa as elsewhere defined in this paper (p. 443). This clay is fine-grained and is eminently suitable for pottery; being in fact used for that purpose at Colesburg in the neighboring county of Delaware. Much of this section is available for the manufacture of shale brick, and will form an excellent hard burned brick. Specimens tested at Bucyrus, Ohio, show that when repressed, it makes a smooth cherry red brick of excellent strength and appearance. Possibly the material can be used for manufacture into pavers, though the relative large amount of lime in proportion to the other fluxes indicates that it would be difficult properly to control the temperature so as not to carry the process of vitrification beyond the desired incipient stage. It is quite probable that some of the shale would prove valuable for sewer pipe.

The use of the shale is limited by the rough topography which makes transportation difficult. There are, however, two points at which transportation is at hand, Kidder, on the

*Daily Express and Herald, June 6, 1857.

Chicago Great Western, and Peosta on the Illinois Central. At either point a good site could be obtained, though in each case the talus of Niagara limestone above would make the stripping tedious. An analysis of the shale as developed at Kidder is given below:

MAQUOKETA SHALE. J B. WEEMS, ANALYST.

	PER CENT.
Silica SiO_2	42.53
Calcium oxide CaO	5.66
Magnesia MgO	4.82
Phosphorus pentoxide P_2O_5	00.00
Ferric oxide Fe_2O_3	5.66
Alumina Al_2O_3	16.83
Potash K_2O	3.70
Soda Na_2O	4.10
Combined water	15.76
Undetermined	.94
Total	100.00

BRICK PLANTS.

August Roeber has a hand yard on Rhomberg avenue, Dubuque. The clay is a loess, obtained on the bluff and carted down to the yard, which is situated on the Wisconsin terrace. It is pugged in pits by horse power, made up by hand, sun-dried, and burned in case kilns. Wood is used in burning, with three to four days of water smoking, and a total burn of seven to eight days. Segers cones show that the temperature of burning is between 1,922° Fahrenheit and 1,938° Fahrenheit, or .05 and .04 of the cone series. The clay burns to a dull salmon red with very little warping. In drying there is a shrinkage by volume of 16.19 per cent and a total shrinkage of 20 per cent. The final brick are $8\frac{1}{4}$x$3\frac{7}{8}$x$2\frac{1}{8}$. The principal market is local, though a certain amount of brick is shipped.

Deitreich Brothers operate, on Lincoln avenue, a plant similar to that just described. The clay here is hauled down, soaked over night and then pugged and made up as before. It burns in eight days with a wood fire and shrinks 11.18 per

cent in burning to ordinary hardness, and 14.68 per cent in hard burning. The finished brick are $8x2\frac{1}{8}x3\frac{7}{8}$ in size.

The D. Meggenberg yard is located on Broadway extended. In this case the loess occurs on the ground, and the pit shows a face of about ten feet, of which the upper half is dark-brown above becoming lighter below. The lower portion shows parallel horizontal bandings and is a light buff color and sandy texture. In work about one-third of the upper clay is mixed with two-thirds of the lower. In drying the brick they are laid flat for six hours and then ricked up.

The Albert Gasser yard is located on Grandview avenue, near the crossing of Dodge street. The loess is here found on the premises and made up as usual, except that instead of being moulded by hand, a horse power machine is used. This resembles the ordinary pug except that moulds are placed in it and by a lever motion the clay is pressed down, filling the mould. This mould is then pushed out in front and an empty one put in its place. The mould which is filled, is hit a slight blow to loosen the clay, and is then dumped on the yard. The moulds are washed in water and sanded before being put in the machine. By this plan some 10,000 brick are made per man, while by hand only about 8,000 are made. It is claimed, too, that the brick are stronger.

John Heim owns two yards. The smaller is a hand plant located near the Gasser yard just described. The larger yard is just off Couler avenue near the Millville road. At this yard the usual loess clay, soaked twenty-four hours, is made up by machine. It is delivered from the pit to a carrier which drops it into the pug-mill. The latter is twelve feet long and is the Monarch type. The clay is moulded in wooden moulds, sanded automatically, and similar to those used at the hand yards. The brick are sun dried and burned in cased kilns at a temperature of about 1,900° Fahrenheit, with a wood fire. The plant includes a twenty-five horse power engine and has a daily capacity of 30,000 brick.

The Kidder brickyard is located on the bottom-land at Kidder crossing, on the Chicago Great Western. Alluvial clay is made up by hand and burned in cased kilns over a wood fire with the usual results.

PIGMENTS.

Within the county there are a number of materials which enter into the composition of modern paints. A large amount of the zinc ore sold from the region is used in the manufacture of zinc oxide; the lead may be so used, though it is here reduced to the metallic form. The Durango iron was first exploited as a pigment, and there are in many of the mines considerable quantities of ocher, which has in some instances yielded good experimental results. Barytes, which is used as an adulterant in white lead, occurs, though it has not as yet been found in quantity. There is an abundance of flint or chert both in Niagara and Galena. This material is suitable, after fine grinding, for use in mixed paints to give them body. Probably the most hopeful field for development is the ocher, which occurs abundantly, may be cheaply mined, and is adapted for use in producing the common darker reds.

ROAD MATERIALS.

The rough topography of the driftless area and the drift border region has made it necessary that more attention should be paid to roads here than is common in Iowa. As a result the county has many miles of excellent roads, and affords an example of what might readily be done with profit in many other portions of the state. The dolomite and limestone occurring so abundantly throughout the county have been chiefly used. These are hand-broken and then spread and rolled on a graded and hard rolled surface. A top dressing of gravel or finer crushed rock and loam make an excellent finishing material. In Dubuque city about 10,000 cubic yards of crushed rock are used yearly for repairs and extensions.

The gravels of the Wisconsin terrace and the Buchanan gravels of Kansan age afford a second important source of road metal. Gravel is used especially in the western portion of the county where rock outcrops are rarer and stone is accordingly higher in price.

FIG 99. Residual cherts on Catfish creek, available for road material.

A third source which is capable of yielding large amounts of excellent material is found in the flint beds. The chert beds of the Niagara, especially, yield a very large amount of flint of sizes suitable for road use with very little additional work. This material is often washed out and concentrated along the streams flowing down from the Niagara escarpment, so that it needs only to be screened to free it from clay to be used. Sections of such gravels, two to twelve feet in thickness, may be found along Catfish and Granger creeks. Flint is much harder than limerock and will accordingly wear much

longer. The macadam made from limestone cuts into ruts very quickly and requires frequent repairs. The flint macadam does not cut so readily; but it does not, when flint is used alone, pack so firmly, and in order to get the best results it is necessary to make the road more carefully and to use a good top dressing, preferably of some ferruginous material.

BUILDING STONES.

Dubuque county is abundantly supplied with a good grade of building stone. The Galena-Trenton and the Niagara are each capable of furnishing moderate and high grade dolomites over a wide area. The large portion of the area which is driftless, and the consequent broken topography render quarry sites abundant. While there is as yet very little stone shipped out of the county, local needs are well supplied, and an increasing trade is being built up. There are four quarry horizons in the county, all yielding dolomitic rock, though the character of the rock from each is somewhat distinctive. The non-dolomitic portion of the Trenton and the Maquoketa yield practically no rock of value in building operations. The stratigraphic position, geographic distribution and general character of the different quarry beds have already been discussed (pp. 417–459) and it is sufficient here to recapitulate.

The lowest quarry horizon of importance is found in the Lower Buff beds of the Trenton. These beds are exposed only along the Mississippi and at the mouths of immediately adjacent streams in the general neighborhood of Specht Ferry. As so situated they have the advantage of transportation at hand, in the C., M. & St. P. railway and the river, but they are not usually accessible by wagon route. Being situated at or near the base of the river bluff they are rarely uncovered enough to be accessible and open to quarrying. The rock itself is of good character. It is a firm, hard, coarse textured dolomite cut by vertical joints and occurring in ledges varying in thickness from eight to ten inches to three feet. In

general the horizon is characterized by a tendency toward thick ledges and massiveness. Practically it is not available except at the angles between the Mississippi and tributary streams where narrow tongues of rock are free from heavy stripping. The horizon includes from ten to twenty-five feet

FIG. 100. Use of Galena dolomite in massive construction.

of suitable rock. It is opened up on the C., M. & St. P. railway about three-fourths of a mile below Specht Ferry and in section 10 of Peru township.

The second important quarry horizon includes the upper portion of the Galena formation, Nos. twelve to fourteen inclusive of the general section (p. 423). This horizon includes from seventy to ninety feet of rock which at various points is more or less quarried. Practically operations are confined to the upper fifty feet. The rock is thin-bedded above, ranging from four to ten inches and separated by thin shaly interlaminations. It becomes more massive below running into

beds four feet and more in thickness. In the earlier operations the thinner, more easily quarried beds above were mainly used, but of recent years more reliance has been placed in the heavier bedded layers below. The rock is hard, completely dolomitized, granular in texture and rough and carious on exposed faces. It does not make a good appearance in dressed stone work but is excellent for ashlar, rough dimension work and coarse masonry. In bridge work, foundations and lower courses in large buildings it makes an excellent appearance. It is used best where the effect of rugged, massive simplicity and strength are desired, but it looks cumbersome in other situations. The stone has high crushing strength and good lasting qualities, but its transverse strength is relatively low. It very rarely shows horizontal laminations or bandings of any kind but is as massive in appearance as granite. This stone has not heretofore been appreciated at its true value, but the Chicago Great Western railway has for several years been using it in their improvement work with excellent effect, and in Dubuque proper, enough has been laid to show its capabilities.

Below the horizon indicated there is a considerable thickness of rock which is more or less quarried for concrete, lime and road material, but less rarely for building stone. Much of it could be used to advantage, though the presence of chert in some portions, and the heavy, massive character of other layers making them difficult to dress, except by machinery, throw them out of competition, for the present, with the more easily quarried beds of the upper horizons.

The leading quarries working on the Galena limestone are located on the Chicago Great Western railway between Graf and Twin Springs, and in Dubuque on Dodge and South Dodge streets, Eighth street, Fourteenth street, and at the crossing of the North Cascade road and the Illinois Central railway. The first named quarry belongs to Mr. T. H. Houston. The beds quarried begin about ten feet below the top of the Galena proper, and the base of the quarry is forty-five feet

below. The stone is in ledges varying from four inches to two and one-half feet, most of it being one foot or more in thickness. It is buff, coarse grained and carious. It is worked by simple hand drills and plug and feather work, with an occasional blast. Horse power cranes are used in han-

Fig. 101. Upper part of Galena limestone, Houston quarry, on Chicago Great Western railway, near Graf.

dling it. The stripping is about ten to twelve feet in thickness and consists of weathered rock which is used for riprap. The quarry produces about seven cars of stone a day, with a working force of eleven men and three boys.

The Dodge street quarries are three in number and include the Tibey, Burns & Saul, and the Jas. Rowan. They show faces of about thirty-five to forty feet, including a portion of the upper thin beds and of the better rock below. These upper beds yield six and eight inch stone, but are not now marketed extensively, and the stone is not of as good quality as that below. The lower beds yield ten to sixteen inch rock, with some running twenty-four and thirty-two inches. In the quarries is the so-called "cap rock," which is normally found immediately above the upper openings in mining operations,

and is about four feet thick. It caps or splits in quarrying, and its massiveness is more apparent than real.

The Eighth street quarry is now worked only for macadam as is true also of quarries on Couler avenue at the foot of Diagonal street, on Broadway and Diagonal, at the end of

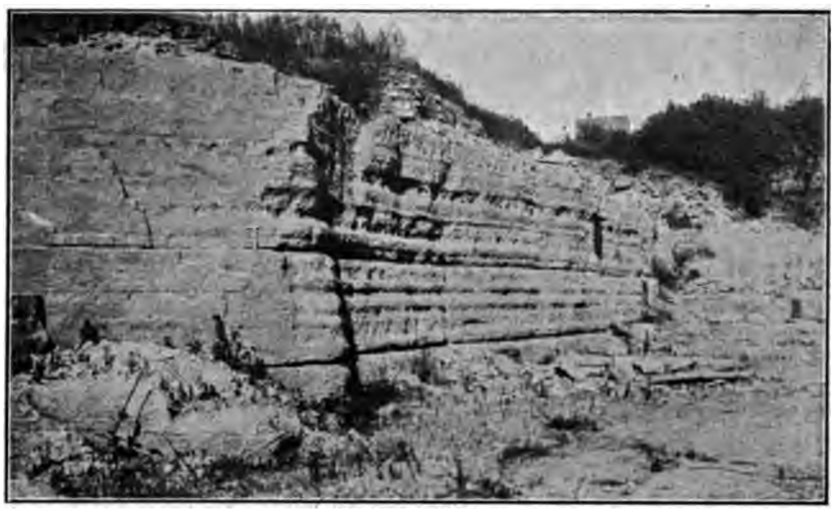


Fig. 102. Galena limestone, Dodson quarry.

Southern avenue, and elsewhere. The Chris Voelker quarry on Wood street and the numerous small quarries near Fourteenth street yield some building stone. The Wm. Dodson quarry on the north Cascade road shows a face about 400 feet long of the beds above and including the cap rock. Throughout the city, and indeed the area of outcrop of the Galena, there are numerous other openings which from time to time are worked for stone.

The Niagara includes two important quarry horizons; the lower and upper quarry beds. The former is immediately above the basal beds, which are fifteen feet thick, and below the chert. It includes about twenty feet of good stone, is worked to advantage in the Farley quarries but has not been opened up very extensively in other parts of the county. The chert breaks down, forming a talus, which readily hides

the quarry beds, and this is probably one reason why they have been quite generally overlooked. At the north Farley quarry belonging to B. N. Arquitt and located on the Chicago Great Western railway, the stone is sawed and dressed by machinery. The plant includes one gangsaw capable of handling rock 6x12 feet, and rubbing bed twelve feet in diameter. The stone tools very easily and in appearance is not unlike the famous Anamosa stone. Figure 52 shows the lower quarry stone as it appears in the east Farley quarries.

At about 165 feet above the lower quarry beds are the upper beds, which have also a normal thickness of about twenty feet. They are opened up at many points but the main quarries are near Cascade. These quarries have already been described. (See page 452).

The Niagara quarry stone, as distinguished from the Galena, is very much finer grained, is usually lighter in color and shows notable laminations. It is a magnesian limestone rather than a dolomite, and occurs in thinner beds. It is better adapted to cut stone work than the Galena, but is not so good for the heavier work. It makes a very pretty wall when laid in broken ashlar with trimmings of whiter dressed stone, as shown by St. Martin's church at Cascade.

ARTESIAN WELLS.

In the course of a general study of the artesian wells of the state Prof. W. H. Norton visited Dubuque and made detailed investigations of the numerous wells which supply such an important amount of water in the city. His notes of the subject are so complete that they are reproduced below.*

*Iowa Geol. Surv., Vol. VI, pp. 208-214.
Since the investigation made by him the water company has drilled new wells and now draws its supply entirely from them.

DUBUQUE ARTESIAN WELLS.

(BY W. H. NORTON.)

	Depth.	Bore—inches.	Elevation of curb, A. T.	Original head.	Present head, A. T.	When finished.	Original flow in gallons per minute.	Present flow in gallons per minute.	Casing.	Water horizons, A. T.	Driller.
1. Linwood cemetery.	1,954	3	706	742	707?	1891	40	20	1,025	-297 to 943	1
2. Linwood cemetery.	1.765	......	776‡	753‡	.....	.....	.....	.....	.....	.....	..
3. Water Works Co...	1,310	10	607	653	.....	1888	2,500?	.....	400	107 to 703	1
4. Butchers' Associa'n	1,000	5	707	740	648	1887	580	.....	.....	.....	1
5. Malting Co.........	999	5	624	.....	.....	1895	.....	.....	.....	.....	2
6. E. Hemmi, dairy...	973	.....	627	.....	.....	1895?	.....	.....	.....	.....	1
7. Bank & Ins. Bldg Co	973	4½	638	648	648	1894	120	120	150	73 and below.	1
8. J. Cushing, factory	965	5	642	673	642	1888	.....	.....	.....	42 and below.	1
9. Packing & Pro. Co.	955	6	607	662	688	1889	340	.....	200	.....	1
10. Lorimer house.....	1,057	5	652	709	658‡	.....	400	0	.....	.....	..
11. Schmidt brewery...	886	6	630	.....	645	1891	.....	.....	80	130 and below.	2
12. Steam Heating Co..	802	4	617	704	617‡	1894	200	0	.....	264, 1,378-163.	1
13. Julien house.......	896	4	615	724	712	.....	480	.....	282	.....	1

1. J. P. Miller & Co.
2. J. Bicksler.

Dubuque probably ranks first among the towns of the state in the output of artesian waters, and is outclassed only by Davenport in the number of its flowing wells.

The first artesian water, so far as reported, springs from the New Richmond horizon of the Oneota at 264 A. T. The second supply mentioned is in the Jordan sandstone from 137 to 107 A. T. Water is reported also from the upper part of the Basal sandstone from 262 to 326 feet below tide, and from 544 to 944 feet below tide. Below the latter depth the Basal sandstone was found to be dry.

The original head of the wells 1,000 feet deep or less seems to have reached from 700 to 740 A. T. In the deeper wells in Linwood cemetery the water rose a few feet higher, perhaps to 753 A. T. In several wells there has been a notable loss of pressure. How far this is due to exhaustion of the local basin is hard to say. In several instances the loss is largely attributable to other causes. After 1887 no well less than 1,000 feet deep headed higher, so far as we know, than 673

‡Approximately.

feet A. T. The head of the well drilled in 1894 at the Bank and Insurance building was only at 648 A. T., about the height of the present heads of the other wells of the class except that of the Julien house. If the water of the latter well still rises to the reported height, 712 A. T., it would show that no serious overdraft on the basin has yet been felt. Unfortunately no report of pressures on the new wells of the Malting Co. and Mr. Hemmi's can be obtained from their owners. While it is very probable that the less deep wells have been multiplied beyond the capacity of the local supply, we find little reason to believe that the lower reservoirs from 514 to 944 feet below tide have been overdrawn.

The following analyses show the exceptionally high quality of the artesian waters of Dubuque:

	GRAINS PER UNITED STATES GALLON.				
	No 1.	No. 2.	No. 3.	No. 4.	No. 5.
Calcium carbonate	7.471	7.2379	9.4559	7.5881	8.096
Magnesium carbonate	3.794	4.4186	4.3775	6.3623	7.179
Calcium sulphate	....	2.1830	1.2841	....	....
Magnesium sulphate	....	....	....	0.2918	....
Sodium sulphate	....	....	....	0.9607	....
Potassium sulphate	....	....	....	....	1.582
Sodium chloride	2.568	2.0488	1.6927	0.3502	0.204
Magnesium chloride	1.926	....	....	....	....
Alumina and Ferric oxide	....	....	....	....	0.035
Silica	....	....	....	....	0.872
Total	20.429	19.2621	20.4295	15.6432	17.968

No. 1. Malting company's well, from 200 to 300 feet. Analysts, Wahl and Henius. Authority, Schmidt Brothers.

No. 2. Malting company, at 900 feet. Analysts, Wahl and Henius. Authority, Schmidt Brothers.

No. 3. Malting company, at 999 feet. Analysts, Wahl and Henius. Authority, Schmidt Brothers.

No. 4. Cushing's well. Analysts, Wahl and Henius. Authority, James Cushing and Son.

No. 5. Steam Heating company. Analysts and authority, C. F. Chandler.

DUBUQUE BANK AND INSURANCE BUILDING COMPANY.

	GRAINS PER U. S. GALLON.	PARTS PER MILLION.
Silica (SiO_2)	.298	5.143
Alumina Al_2O_3) and Ferric Oxide (Fe_2O_3)	.646	11.143
Lime (CaO)	4.118	71.000
Magnesia (MgO)	2.378	41.000
Potash (K_2O)	......	. ....
Soda (Na_2O)	1.665	28.714
Chlorine (Cl)	Trace	Trace
Sulphur trioxide (SO_3)	.996	17.143
Carbon dioxide (CO_2)	11.658	201.000
Water in combination (H_2O).	2.129	36.714
UNITED AS FOLLOWS.		
Calcium bicarbonate (CaH_2) $(CO_3)_2$)	9.587	165.287
Calcium carbonate ($CaCO_3$)	1.434	24.714
Magnesium bicarbonate (MgH_2 $(CO_3)_2$)	8.625	148.714
Sodium carbonate (Na_2CO_3)	1.533	26.428
Sodium sulphate (Na_2SO_4)	1.765	30.428
Alumina (Al_2O_3) and oxide of iron	.646	11.143
Silica (SiO_2)	.298	5.143
Solids	23.888	411.857

Analyst, Dr. J. B. Weems. Date, May 30, 1896.

Several engineers report that the water corrodes iron pipes and makes some scale. The deeper waters of the Linwood cemetery wells are said to be poor as drinking water. Sanitary analyses of artesian waters have seldom been asked for, and the following of the well of the Bank & Insurance Building company, by E. W. Rockwood, is of interest as showing the high organic purity of waters of this class:

	PARTS PER MILLION.
Total solids	277.000
Loss on ignition (no charring or odor)	62.000
Free ammonia	.016
Albuminoid ammonia	.006
Chlorine	......
Nitrates	......
Nitrites	......
Sediment	......

Color none, odor none, taste good.

Equally significant is a bacterial analysis made by Dr. G. Minges, of Dubuque, of the water of the artesian well of the

water company, in which he found but twenty bacteria to the cubic centimeter.

The artesian wells contribute but a portion of the water furnished by the water company. A large amount of excellent water is furnished by an abandoned tunnel in the bluff, two and one-half miles from the city, one mile in length and about 100 feet below the surface, which was once used to drain mines. A third supply is obtained at Eagle Point, 500 feet from the bank of the Mississippi, from 300 drive wells from thirty to sixty feet deep. The impression prevails that this supply is derived from the river by filtration through its banks of sand. This is not the case. The water is common surface or ground water, and its contamination is shown by a bacterial analysis by Dr. Minges, who found as high as 5,290 bacteria to the centimeter in water taken directly from this pumping station. Under these conditions the advice given of late years by some physicians of the town to consumers to boil all drinking water has not been untimely.

Belonging to the same local basin is the town well at East Dubuque, from which 750,000 gallons are pumped daily. The well is 983 feet deep, bore six inches, and registers a pressure of thirteen pounds. One hundred feet of red shale, the Saint Lawrence, were reported as lying near the bottom of the boring.

A curious fluctuation has been noticed in the well of James Cushing & Son, the discharge sometimes being much more than at others. In the deeper well at Linwood cemetery the tubing is sometimes obstructed by a "fibrous sediment," probably crenothrix. The removal of this by churning an iron rod in the tube has doubled the diminished flow.

*For the facts relating to the wells at Dubuque, we are under obligations to H. S. Hetherington, who donated a tube of samples from the Steam Heating company's well; to Dr. W. Watson, Mr. Jas. Beach, and to several owners of the wells. Mr. W. H. Knowlton, city engineer, kindly supplies the elevations of the curbs, except that of No. 2, Linwood cemetery, which is estimated by one of our correspondents.

RECORD OF STRATA.

Driller's log of Steam Heating Co.'s well:

		THICKNESS.	DEPTH.
15.	(Alluvium) "depth to rock"	165	165
14.	"Sandstone"	6	171
13.	"Sand and shale"	5	176
12.	"Limestone, white"	128	304
11.	"Limestone, gray"	42	346
10.	"Sand and lime" (inspection of the tube shows that this includes a cherty limestone, perhaps arenaceous, a gray limestone and lowest a brown, cherty, arenaceous limestone)	135	481
9.	"Sandstone," brown	20	501
8.	"Marl," yellow	3	504
7.	"Sand and lime"	10	514
6.	"Sandstone"	62	576
5.	"Lime"	18	594
4.	"Marl, red"	87	681
3.	"Shale, sandy," green	64	745
2.	"Marl, red"	10	755
1.	"Sandstone" cream yellow	48	803

DESCRIPTION OF DRILLINGS OF SCHMIDT'S BREWERY WELL.

		DEPTH OF SAMPLE.
25.	Sand and gravel	25
24.	Sand, yellow	30
23.	Sand, reddish	56
22.	Dolomite, buff, aspect of Galena, samples at 60 and 65 feet	60 and 65
21.	Limestone, dark bluish-gray and buff	80
20.	Limestone, magnesian, or dolomite, dark drab, mottled with lighter color, in small angular fragments, residue after solution large, argillaceous, siliceous and pyritiferous, three samples	100 to 114
19.	Sandstone, white, moderately coarse, grains rounded smooth, and comparatively uniform in size	126
18.	Dolomite, light yellow gray, nearly white, with much sand in drillings	140
17.	Sandstone, as No. 19	156
16.	Dolomite, drillings chiefly chert	189
15.	Dolomite, gray, highly cherty at 250 from	210 to 250
14.	Sandstone, white, many grains faceted, some dolomite chips in drillings	254
13.	Dolomite, light buff, in fine sand, with chert and quartz sand	258
12.	Sandstone, white, with calcareous cement	267
11.	Unknown, no samples or record	...
10.	Dolomite, buff, cherty	426

9. Dolomite, brown, chippings splintery, mostly of flint with some of drusy quartz........................ 430
8. Sandstone, cream yellow, moderately fine, calciferous as shown by dolomitic and cherty material in drillings, three samples....................465 to 474
7. Dolomite, buff in fine sand, with some quartz sand.. 478
6. Sandstone, light reddish-yellow, fine, calciferous... 535
5. Dolomite, in fine buff sand and gray chips.....581 to 584½
4. Shale, highly arenaceous, glauconiferous, in chips which pulverize into reddish-yellow powder (at 632 feet) and reddish-brown (at 636 feet), quartzose matter microscopic and angular..............632–636
3. Dolomite, highly arenaceous, glauconiferous, in fine brown angular sand at 724 and in coarser sand at 726..724–726
2. Sandstone, yellow, grains moderately fine, the larger rounded and smoothed 730
1. Sandstone, pure, white, grains rounded, moderately fine 841

DRILLER'S LOG OF JULIEN HOUSE WELL.

		THICKNESS.	DEPTH.
10.	Depth to rock	210	210
9.	Sandstone	160	370
8.	Marl	66	436
7.	Sand, marl and lime mixed	50	486
6.	Sandstone	60	546
5.	Limestone	105	651
4.	Marl, red	40	691
3.	Shale, sandy	46	737
2.	Marl, red	7	744
1.	Sandstone	141	885

SUMMARY.

The wells of the lower town pierce the alluvial deposits which fill a preglacial or interglacial channel of the Mississippi river. The elevation of the fluvial floor of rock at the Steam Heating company's well is 452 feet A. T., and at the Julien house, 405 feet A. T. if the record can be trusted. Schmidt's brewery stands near the cliffs of the present gorge and here rock lies at 570 feet A. T.

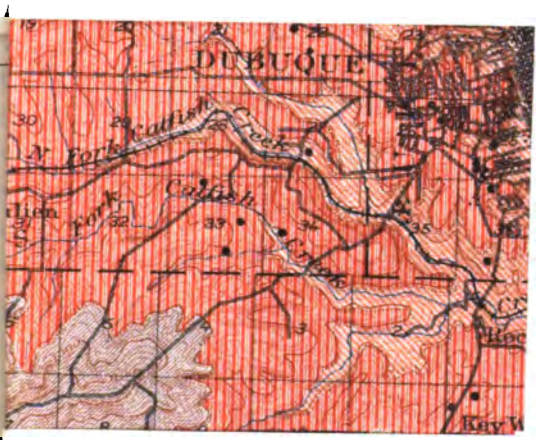
The record of the Julien house well falls in with the other records only in part, but the samples of the Schmidt well are in close agreement with the record of the Steam Heating company. Combining these data we have the following section:

	THICKNESS.	BASE A. T.
Galena		550
Trenton	46	504
Saint Peter	58	446
Oneota	310	136
Jordan	95	41
Saint Lawrence	179	-138
Basal sandstone	1,110	-1,248

CEMENT.

Between the Galena and Maquoketa there are certain transition beds normally about twenty feet thick. These are yellow in color, uniform in texture and composition and grind easily. They contain 83.50 per cent of calcium and magnesium carbonates about equal in proportion and are well adapted as regards character to the manufacture of cement. They also can be found in favorable situations as regards transportation facilities. As has already been noted certain of the layers in the quarry of the Eagle Point lime works are also suitable for cement manufacture. It would, however, be impossible to make a Portland out of either of these rocks and in the present conditions of the trade there is no encouragement for new plants for the manufacture of the cheaper natural cement.

The Trenton, as will be suggested by the analyses given, is a non-magnesian rock and when it occurs in favorable situation as regards transportation and clay, might well be used for making Portland. Some excellent samples have been collected and tested but so far no body of the rock has been found sufficiently free from magnesia and sufficiently extensive and uniform, to warrant investment. Possibly more detailed studies over the whole Trenton area would bring to light one or more such situations. In appearance and character the rock is very much like that of the Lehigh region which is so extensively used in cement work.


DUBUQUE
Catfish

FORESTRY NOTES FOR DUBUQUE COUNTY.

BY THOMAS H. MACBRIDE.

Dubuque county is one of the so-called "river counties" of the state of Iowa. The primeval forest of the county, accordingly, formed a part of that narrow isthmus of woodland, which, following the banks of the Mississippi river, connected the great forest areas of the north and south, of Minnesota and Missouri. The narrowness of this belt may be inferred when we reflect that in Iowa at least it nowhere involved the width of a single county. Its westward extensions, too, were narrow, almost uniformly confined to the banks and valleys of streams tributary to the greater river. Dubuque county, perhaps even better than any other, affords an excellent illustration of the general situation. Though one of the best wooded regions of the state many of its townships were chiefly treeless prairie. Liberty, New Wine, Dodge, Vernon and Prairie Creek, though not wholly without forest, were yet called prairie townships, while Taylor, Washington, White Water and even Julien, by the very banks of the river, were prairie in proportions by no means small. Groves of great white oaks marked the ridges of yellow clay or loess, similar clusters of bur oak crowned the rocky hills of the driftless area, while bur oak and black jack vied with each other, generally to the disadvantage of the former, in an effort to occupy the poorer soils where erosion had spread out the sands and gravels of the drift. Only in the protected gorges of the driftless regions and along the steep bluffs facing the

Mississippi, typical forest conditions prevailed and trees in greatest variety found foothold and flourished.

On the advent of civilization the checking of prairie fires gave the forest here, as elsewhere, great relief. Young trees came up in every direction, partly from seeds, partly from so-called bench-grubs, old stump-like stocks which had been in the days of prairie fires again and again burned off, only to start again in shoots and suckers with the advent of spring; but destined so long as the fires swept over them, never to attain tree-like dimensions. These bench-grubs sometimes were very old and possessed an extensive root system. This accounts in part for the rapidity with which the forests of Iowa began to spread with the arrival of civilized men. In the case before us the early farmers selected, of course, the more level country; the steeper and poorer hills were left to nature and became quickly forested, covered with what is called second-growth, an assemblage of trees denser and darker than ever occur in nature under any other circumstances. In Julien and Peru townships some of these second-growth forests may yet be seen which have been growing at least fifty or sixty years. So that the oft-repeated remark as to the number of Iowa trees, to the effect that their number has greatly increased since the country has been settled, is strictly true.

In these later years, however, the rapid increase in land-values has changed entirely the forest situation in Dubuque county as everywhere else in the state. The second-growth is being rapidly cleared away and the surviving trees of the old forest, the great white oaks and bur oaks, have been hurried to the sawmill to make cheap lumber for all manner of domestic use. Every foot of land on which the plough may be made to pass is coveted for agriculture, and the forest as a whole is doomed. Fine bodies of second-growth are still to be seen, to be sure, but their respite is due not to any policy of forest preservation—the average farmer knows nothing about such a thing—but simply to the fact that time

and strength have not as yet availed to effect the clearing. Even the rocky heights and gorges of the driftless region are being rapidly denuded, as anyone may observe who passes on the train down the valley of historic Catfish creek, and, on plea of securing blue-grass pasture, all the natural covering of these rougher portions of the country is rapidly disappearing, leaving for the most part bare limestone rocks and walls to bleach and burn in the summer sun. In such ill-advised agriculture the loss to the farmer is three-fold; he loses his trees, which if properly cared for might have furnished his holding, generation after generation, with a most convenient source of supply for posts, fuel, and wood to meet all sorts of needs upon the farm; he loses his land, for no sooner have the stumps rotted than in many places the soil begins to wash and blow away, so that fields may be shown to-day where there is nothing but rock; he loses often lower-lying good land which is destroyed by the wash spread out from the cleared hilltops. Nay, the loss is greater still; the farmer who thus strips the gorges and rocky hillsides of their forests withdraws permanently what ought to be his contribution to the maintenance of his county's water-supply as represented in springs and streams. Take the woods from Pine Hollow, for instance, and forthwith every stream will go dry, every fountain vanish. Fountains and streams go with woods. They are habitually so associated in speech, in all literature, and the result of forest-removal as affecting the water-courses of a country is perfectly well understood. Not only do the streams, uncovered by forest shades, dry up in summer, but, what is worse, they become in spring and winter rushing, ungovernable torrents, destroying all fields and meadows wherever they go. Every man who comes to us from Austria, France, or Switzerland knows the truth of this statement; but we need by no means go so far for illustration; the farmers of Dubuque and Delaware counties may see the situation for themselves as they drive along the highways. All the experiences of older nations and people

confirm those conclusions in this matter which are suggested by our daily observations upon our own farms, to the effect that the extirpation of native forest is the worst sort of political economy, and that the highest type of agriculture is impossible where the forest has not its allotted place and where trees are no longer allowed to perform their beneficent work.

But there is still another side to this question as presented by the situation in the county before us. The time has passed, if ever it existed, when the welfare of the county was measured wholly by the records of the freight conductor. The homes of men are something better than even granaries and barns. The great number of our farmers realize that the farm should be beautiful as well as productive, especially when productiveness and beauty are entirely compatible and consistent with each other. Farm values in Dubuque county are reckoned in accordance with the "improvements" carried. If these improvements are attractive the farm is salable at high price; if unattractive, the farm is proportionately cheap. Now nothing shows more natural beauty on a piece of land than a grove of trees, especially if it shade rocks and running water. The farmers of Dubuque county have wonderful opportunity in this direction. Nature has been extremely generous. Whereas men of the prairie counties must perforce plant and cultivate their groves and every tree that shall shelter or decorate their holdings, the happier husbandmen of Dubuque find almost everywhere trees and groves as part of nature's gift. They have only to preserve what nature offers to show landscapes fair as those of old Luxemburg, Austria or Bavaria. On the other hand nothing is more unsightly than the bare cliffs and rocks of Niagara or Galena limestone, nothing as absolutely unproductive. The rocky hills and bluffs of Dubuque county, once they are entirely denuded of their woods, their natural covering, will present a scene of desolation entirely out of harmony with the name and fame of Iowa.

Further than this our problem reaches. For, where the timber holdings of the farmers are grouped together we get the effect of a public park. After what has been said it is hardly necessary here to say that no county in the state offers for public resort more beautiful or attractive natural facilities. The wooded bluffs about Dubuque should be made a common where those delightful shades and majestic scenes and views might be for the perpetual enjoyment of all the people. As this is written comes the word that a movement is already on foot to do something of this sort. Mr. Stout's gift to the city of a considerable tract of park land is a beginning and should at least serve to call attention to the wonderful park possibilities which form the magnificent suburbs to the old Key City of this state.

But is there any reason why even a public park should be the adjunct and property of the city only? People, especially in Iowa, do not all, by any means, live in cities. The several country towns or townships of Dubuque county may also use and enjoy the gentle and humane iufluence of the well-kept field of nature. The great forests of the old world are free to the poorest comer, and the people enjoy their glories and are happy. These parks are not in the cities always; they are forest reserves on the hills and mountains, and by the rivers and streams. No people can so cheaply enjoy such parks as can the people of eastern Iowa. In Dubuque county the people of Liberty, New Wine, and Concord townships, have at hand in Pine Hollow, a park, the gift of nature, which centuries of human effort might hardly produce. Here are deep shades rocky walls, trees and shrubs of every species indigenous to the soil, bubbling springs, with abundant waters—what can we ask for more? Pine Hollow is to-day but a series of wood-lots owned by a hundred farmers. All it needs is judicious management, the building of a few bridges, with roads and paths and the communities of New Wine, Luxemburg, and Georgetown would have the most delightful park in northern Iowa. The region should belong to a corporation,

to an association of the parishes, say, immediately adjoining. As the wood-lots, one by one, are offered for sale, they should be purchased by the corporation, or parish even, that the forest as a whole be not destroyed piece-meal by thoughtless individual owners. If the whole valley were under one control the destruction caused by "wood-rats," timber-thieves, would be greatly lessened, if not entirely stopped, since means could be easily adopted to effectually exclude all depredators and trespassers.

But, it will be asked, what can be done for those sections of this county which, through thoughtlessness, have been exposed already to the destruction of the elements? What shall we do with that dry ravine, that rocky hilltop? that barren cliff? It was once wooded; now it produces nothing and mars the beauty of the farm; can it be redeemed? Of course, the only hope lies in replanting, reforestation. We must remember that nature has spent ages in bringing about the condition of affairs which we have disturbed, and such is the peculiarity of our Iowa climate, that the re-establishment of wooded conditions anywhere with all our pains and skill is likely to be a matter of much difficulty. But it is feasible; it can be done. By means of planted groves forest conditions have been set up in central Kansas, and the same thing can therefore much more hopefully be attempted here, where the rainfall is so much greater. Trees in the places referred to are not likely to come up of themselves. Here and there, in time, such might be the case; but we must not wait for this. A tree plantation must be established, protected summer and winter from the ravages of cattle, cared for as any other crop, if success is to be made sure.

One of the far-reaching plans inaugurated by the present United States Commissioner of Forestry, provides intelligent and efficient assistance, without cost, to any and every farmer who desires to redeem, by tree planting, the waste lands of his

demesne, or holding, and land owners are invited to correspond with the Secretary of Agriculture at Washington on this most important matter.

In any event Dubuque county offers for experiment in this reform one of the most favorable regions of the state, and it is hoped that the intelligence and patriotism of her farmers may soon find expression in the restoration and preservation of her beautiful groves and forests, not alone by the establishment of public parks, but in the maintenance of smaller groves and thickets, covering the rocks and sands, and giving to the county a landscape beauty and charm difficult to rival. When we begin replanting, a list of such woody plants as are or were indigenous to the region becomes in a high degree a thing of practical value. Such a list here follows.

It will be observed that the list of woody plants for Dubuque county is almost identical with that made out in these reports by Mr. Cameron for Delaware county.* Clayton county will probably yield a similar list which may again be compared with that of Allamakee county.† All these counties share in the driftless area of the state and exhibit the richer variety of forest species which that peculiar region seems everywhere to afford. In fact so characteristic is the flora of the area in question, as found in Iowa, at least, that the presence of certain species in any locality is sufficient to raise the inference at once that the station has never been visited by the drift. The White pine, *Pinus strobus* L., is not known native in Iowa except in driftless regions, or in their immediate vicinity. The same is true of the Paper birch, *Betula papyrifera* Marsh., the Witch-hazel, *Hammamelis virginiana* L., besides a number of herbaceous plants rare to our flora. A most interesting problem touching the relationship of present vegetation to the present geologic changes is suggested by these peculiarities in distribution, but we are not as yet in possession of sufficient data to warrant generalization.

*Rep. Iowa Geol. Surv., Vol. VIII, pp. 193-9.
†Rep. Iowa Geol. Surv., Vol. IV, pp. 112-120.

The season or period of drought through which Iowa has for several years prior to 1899 been passing has left its mark in the forests as elsewhere. In the second-growth woods of Dubuque county there are to-day thousands of dead trees, dead of drought.

This must not be reckoned an occasion of special alarm. It is simply nature's method of thinning her forests. In any systematic treatment of a forest plantation trees are continually removed. They must be, in order that individuals of the various kinds and species may attain characteristic perfection. Nature thins by removing in a dry seasons the weaker, the less advantageously placed, the over-shadowed and over-crowded.

This is an illustration in a broad way of what naturalists sometimes call the "survival of the fittest." Of course the survival while preserving in the long run the fittest for the great and far-reaching purposes of nature may not result to our convenience at all. We may see our oaks and hickories dying in numbers while aspen-trees, locusts, willows and elms remain. The wise farmer will take heed to such a situation, removing in time the less valuable species and so establishing year by year a forest of oak or hickory.

In short, the time has come in Iowa and throughout the northern states when forestry, the cultivation of trees in forests, is to be a matter not of shelter and ornament only but of profit, and those who earliest realize the situation will soonest find the reward of their wisdom and foresight.

The list of woody plants and trees in Dubuque county is as follows:*

*For much aid in preparing this list the author makes acknowledgment to Miss Emma R. McGee, of Farley, Iowa, and to Prof. Jno. A. Anderson, of Dubuque.

ANGIOSPERMÆ.

Dicotyledones.

TILIACEÆ.

Tilia americana Linn. Basswood. Linden. American Linden. This is a beautiful, rapid-growing tree, growing best in rich soils, but thriving on rocky hillsides, especially along water courses. One of our finest shade trees, growing well when transplanted to the loess, or clay hills, and certain to be of greatest use in reforestation. The wood is soft, of little use as fuel but yielding a light easily worked lumber useful in construction of furniture, machinery, and even in interior finish of houses. Common; but large trees have been mostly cut out.

RUTACEÆ.

Xanthoxylon americanum Mill. Prickly Ash. A common shrub, along streams; liable to form thickets several acres in extent. This is a very pleasing ornamental shrub and grows well even in dry soils. The flowers are of two kinds, sterile and fertile, appearing before the leaves and on different plants. The reddish berries are very pretty in fall, but to secure the production of these in any case, shrubs of the two sorts, that is those having the fertile and those having sterile flowers, must be planted near each other.

CELASTRACEÆ.

Celastrus scandens Linn. Climbing Bittersweet. Bittersweet. Not infrequent on wooded hillsides, in thickets and by hedge rows. Climbing by coiling about the stems of shrubs or small trees, it sometimes overspreads and suffocates its support; sometimes chokes the stem by the closeness of its coils. Its bright red berries in fall are brilliant decorations of the woodland and, as the vine is easily transplanted, it should have a prominent place in the adornment of home grounds and farms.

Euonymus atropurpureus Jacq. Wahoo. Waahoo. Burning Bush. An elegant shrub, sometimes reaching a height of fifteen feet, rather rare everywhere, but still found along streams on rocky banks, as of the Mississippi bluffs, in Pine creek hollow, etc. Another valuable ornamental tree. Its curious four-parted purple flowers are part of the glory of June, and the no less remarkable, lobate, scarlet fruit, likewise contributes not a little to the beauty of our autumn.

RHAMNACEÆ.

Ceanothus americanus Linn. Jersey Tea. Common on half wooded prairie hills, and even out on the prairie, but more frequently at the thicket edge or near the bur oak clump. Formerly abundant in Dubuque county. A perennial with hard, woody, reddish roots, whence sometimes called red root, bearing very pretty white clusters of flowers from the shoots of the season. Well worthy of a place on every lawn.

Rhamnus lanceolata Purrsh. Buck-thorn. Prof. Hnderson reports this common in certain localities. It is common over the eastern part of the state wherever there is forest.

VITACEÆ.

Vitis cordifolia Michx. Wild Grape. Frost Grape. So called, because in this latitude the fruit is palatable only after a pretty severe frost. This is the common wild grape of the Mississippi valley. It flourishes in all wooded or semi-wooded regions, covers the rocks and binds the thickets; its bloom lends the most delicate perfume of spring, and its fruit in fall, now eagerly sought by flocks of south-moving birds, was once prime part of the store and treasure of the pioneer. Wild grapes when thoroughly ripe possess a most delicate flavor, and, under the manipulations of the skillful housewife, are said to be unequaled for the manufacture of conserves and jellies.

Ampelopsis quinquefolia Michx. Woodbine. Virginia Creeper. Five-leaved Ivy. American Ivy. An exceedingly

common woody-vine in all parts of the county; in the woods and by the hedge-rows or fence-rows on the prairie farms. Commonly cultivated as an arbor or porch plant, for which purpose in our climate there is nothing better. The fruit is in autumn purple, resembling somewhat the looser clusters of small grapes. The very best plant in the world to cover the bare rocks of this county, and all sorts of denuded cliffs and crags.

SAPINDACEÆ.

Acer dasycarpum Ehrh. Soft Maple. White Maple; or even sometimes called Silver Maple. Common on river and creek bottoms everywhere. Perhaps more commonly planted in Dubuque county, and indeed in all eastern Iowa, than any other tree. The rich alluvial soils along the streams form the favorite habitat, and a splendid grove of these trees now stands near the mouth of Maquoketa creek in Peru township. soft maples make rapid growth, furnish an excellent quality of fuel, and yield to the cabinet and furniture-maker a useful Soft white lumber. Recent authors in forestry write this species down as *Acer saccharinum* Linn.

Acer saccharinum Wang. Sugar Maple. Rock Maple. Hard Maple. Once a very common tree throughout the county; now represented chiefly by small trees in the so-called "second growth." Along the face of the Mississippi river bluffs, and on rocky banks in all limestone regions. Of the primeval woods, some few large trees still survive in Pine Hollow. A tree of comparatively slow growth, but of surpassing excellence. As a shade tree its dense foliage is unequaled; for fuel there is no better wood, while the lumberman prizes hard maple lumber among his choicest products. The trees of this species do not well bear transplanting from the forest. True, they seem to flourish for years, but they do not by any means reach the normal size and sooner or later die at the top and perish, perhaps fifteen or twenty years after planting. Trees from the seed do much better. One

difficulty, no doubt, is the fact that transplanted trees are set singly or in rows. The hard maple is above all a forest tree and flourishes in forest conditions only. Single trees in Iowa succumb to drought. By observing such precautions as will make our efforts conform to the known habit of the species, there is no reason why maple orchards may not again stand in Iowa, as they have been more than once renewed in New England and New York.

By some recent writers this species is called *Acer saccharum* Marshall.

Acer spicatum Lamarck. Mountain Maple. Moose Maple. This is a shrubby species tending to form thickets. It never attains the stature of a tree. It is immediately recognized by the circumstance that its flower-clusters are erect, spicate racemes, appearing *after* the leaves. Valuable as an ornamental shrub. Doubtfully referred to Dubuque county, but to be looked for on the steep sides of the bluffs facing the Mississippi river.

Negundo aceroides Moench. Box Elder. This is another species exceedingly common in cultivation. Everywhere planted for shade and shelter, and for both purposes excellent. Valuable also as a nurse for trees of other species, that is, to be planted as a temporary protection to more valuable species. Miss McGee reports the box elder native along the Maquoketa river in Cascade township, and the species was no doubt indigenous in all parts of the county. It starts very rapidly from the seeds in all sorts of localities.

This should probably be called *Acer negundo* Linn, and for common name, Ash-leaved Maple is in some places preferred.

Staphylea trifolia Linn. Bladder-nut. A shrub six to ten feet high, common in all the wooded parts of the county. Valuable as an ornamental plant. It blooms early and remains long in flower, the whole tree being for a time a mass of blossoms, not especially showy, but very beautiful withal. The bush well deserves a place in every dooryard but should be planted where it can have plenty of room, as it

tends to sprout from the roots and will make a thicket. In late summer the twigs are hung with curious, three-sided, whitish, inflated pods in which the nut-like seeds lie loosely, whence the popular name.

ANACARDIACEÆ.

Rhus typhina Linn. Velvet Sumac. Staghorn Sumac. Eastern Sumac. Common in all the northern part of Dubuque county and probably extending along the Mississippi river southwards. A most beautiful shrub or small tree. Specimens six inches in diameter and twenty feet high occur along the bluffs. On high rocky ground everywhere. Valuable only as an ornamental plant, for which purpose it is, among native species, unexcelled. The brown velvety branches, the profuse delicate foliage, the crimson clusters of pilose berries, make a series of attractions that should commend the velvet sumac to every lover of the beautiful.

Linne is said to have given to this plant an earlier name, *Datisca hirta*, and recent authors write *Rhus hirta* (Linn.) Sudworth.

Rhus glabra Linn. Sumac. Common Sumac. Smooth Sumac. Everywhere throughout the county. Only a little less desirable as an ornamental shrub than the species last mentioned. Should be planted as a screen, or to border or fringe the grove, where in autumn its scarlet foliage lends an inexpressible cheer to the fading landscape.

Rhus toxicodendron Linn. Poison Ivy. Poison Oak. Poison Sumac. Common everywhere and exceedingly variable. Little affected by the cultivation of the country, as it occurs to-day quite as often in the city lawn as in the woodland pasture. In the "poison oak" variety it is a low, large-leaved, shrubby-looking plant, sometimes only a few inches high and resembling a young jack oak; but it blooms and fruits, in such humble guise, quite as freely as when it stands a bush five or six feet high, or as a creeping vine it climbs a hundred feet to the summit of some forest tree, fast clutching the bark of the

supporting stem by millions of fibrous insinuating or adhesive rootlets. An unmitigated nuisance, although the number of persons affected by the poisonous quality of the plant would seem to be small. The plant is omnipresent, and cases of poisoning certainly not frequent. Fruit in autumn dry, white, or whitish.

Rhus canadensis Marsh. Sweet-scented Sumac. This occurs probably in the county. It is reported from Delaware and Clayton counties. In foliage it resembles the preceding, but has the fruit of the other species. "Ye shall know them by their fruits."

LEGUMINOSÆ.

Amorpha fruticosa Linn. False Indigo. A shrub five or six feet high, with profuse purple bloom in July and August. Not uncommon along the sandy banks of streams and by the river front.

Robinia pseudacacia Linn. Locust. Black Locust. A commonly planted tree and in not a few places escaped from cultivation, though probably not indigenous. In the last twenty or thirty years the tree has been almost ruined by borers. Fortunately these enemies are just now less injurious and locusts are coming in again. We have no tree of rapid growth which can compare with this for excellence and density of wood. The stems six inches in diameter make the very best of posts.

Gleditschia triacanthos Linn. Honey Locust. Not uncommon in the northern part of the county. Probably to be found in all parts of the wooded region. A magnificent tree well worthy of cultivation. The wood is heavy and hard, admits of a beautiful polish, and is useful for all sorts of purposes. Like the black locust the tree grows rapidly, and is easily cultivated from the seed. A thornless variety may be obtained from nurserymen and is to be preferred. Linnæus is reported to have at first written *Gleditsia*, and so the name in some lists appears; but surely reformed nomenclature does not sanction bad orthography!

Gymnocladus canadensis Lam. Kentucky Coffee Tree. Reported not rare in the eastern part of the county, probably to be found in the wooded districts everywhere. A very handsome ornamental tree of rapid growth and yielding valuable wood. The heart-wood is of a fine brown color, takes an elegant polish, is hard, heavy and durable. For outdoor use, posts, rails, etc., there is nothing better. As an ornamental tree, the soft, abundant foliage commends it in summer, and the curious twigless branches in the leafless season make it attractive by contrast with the winter habits of other arboreous forms of vegetation. The flowers produce comparatively little fruit, and the seeds are with difficulty made to grow, sometimes not until the third year after planting. Propagation is best effected by shoots and root-cuttings. The tree is easily transplanted and has few or no insect enemies, such as borers and the like. "Abundant at Eagle Point."—*Anderson.*

ROSACEÆ.

Prunus americana Marsh. Wild Plum. Not uncommon; forming thickets in all parts of the county, but of late much injured by drought and by cattle. The fruit is excellent, and since the trees are perfectly hardy it is a matter of wonder that the farmers do not attempt the preservation of our wild plums rather than the cultivation of uncertain varieties offered by traveling "tree men." Besides the bloom of the wild plum makes it most desirable as an ornamental tree. A plum thicket in full bloom is worth going miles to see, and the sweetness of its delicate perfume is proverbial.

Prunus chicasa Michx. Chickasaw Plum. Red Plum. A tree less common than the last, the fruit and stone smaller, red, very sweet when ripe. All the good things known of the preceding species are also true of this. Quite abundant near the upper end of Pine Hollow. This will perhaps be called later on *Prunus angustifolia* Marsh.

Prunus virginiana Linn. Choke Cherry. A small tree, not uncommon throughout. Chiefly valuable for purposes of ornament. Like some other shrubs here listed, it sends up shoots from the roots and is liable to form a thicket.

Prunus serotina Ehrh. Wild Cherry. Black Cherry. A beautiful tree, widely distributed; common in all the groves of second-growth visited. Rapid growing, it yet forms a dense, fine-grained wood, most valuable for all purposes where fine finish is desirable. Endures shade well and will prove extremely useful in forest planting.

Physocarpus opulifolius Maxim. Nine-bark. A pretty shrub, common in adjoining counties on rocky banks and probably in Dubuque county, though not noticed by the present author.

Rubus strigosus Michx. Wild Red Raspberry. Widely distributed by birds and not uncommon in waste places.

Rubus occidentalis Linn. Black Raspberry. Occurs in dry places and fields with the last mentioned.

Rubus villosus Aiton. Blackberry. Said to have been formerly very common. All these forms are now largely tramped out by cattle in the overcrowded pastures.

Rosa blanda Aiton. Wild Rose. This is the common wild rose of the Mississippi valley. Frequent in sandy soil and on dry hills everywhere. The flowers are very handsome but "single" and of short duration.

Pyrus coronaria Linn. Crab-apple, Wild Crab, Sweet Crab. Sweet-scented Crab. Not uncommon in thickets along hill-sides and by streams, Crab-apple trees deserve protection at the hands of every farmer. When in bloom they are the most beautiful object of the landscape and even the fruit is not without its admirers. It should be planted in corners where it may have full room to send up shoots. A single tree in this way will soon originate the characteristic thicket. Strange to say during these later droughty years, the crab-apple like its congeners has suffered much from pear-blight!

The name given by Linnæus shows that the beauty of the tree 100 years ago did not lack appreciation; *coronaria* means suitable for crowns and garlands.

Cratægus coccinea Linn. Scarlet Haw. Red Haw. White Thorn. Hawthorn. Not uncommon in woodlands throughout the county. Another of our most valuable ornamental trees. Its white flowers yield in beauty to those of the crab-apple only while it has the added advantage of its autumn-gladdening scarlet fruit. The variety *mollis* of Torrey and Gray is more common with us in eastern Iowa. It has downy twigs, blooms earlier and grows to large size. Specimens are often twenty and sometimes thirty feet high.

Cratægus crus-galli Linn. Cockspur. Cockspur-thorn. Not common. One specimen was observed in Peru township, but it doubtless occurs in all parts of the county, along creek and river bottoms. Less desirable than the other thorns, by reason of its spininess. The thorns are stout but slender, sometimes three inches in length. The flowers are showy and profuse but ill-scented. Nevertheless the bush deserves a place on the lawn or by the hedgerow. The species is suggested as a hedge-plant for which it would be excellent, but that in such situations all the hawthorns suffer greatly from apple borers and are consequently disappointing.

Cratægus tomentosa Linn. Thorn-apple. Miss McGee reports this from this county. It is given in Mr. Cameron's list for Delaware county immediately west. It is distinguished from *C. coccinea mollis* by the larger leaves, densely pubescent beneath, serrate and with margined petiole, the flowers small, ill-scented, fruit small and dull red, not scarlet. Anderson reports this form common.

Amelanchier canadensis (Linn) Medic. Shad-bush. Service-berry. Juneberry. Common on rocky hillsides everywhere, wherever such localities are still wooded. Seems to prefer southern and western exposures. A handsome bush or small tree; usually ten to fifteen feet high, but sometimes twenty to thirty. The racemes of lovely snowy flowers appearing

before the leaves in early spring make this one of the most welcome harbingers of vernal life's return. The species runs into many varieties to the delight of nurserymen. Most forms differ, however, chiefly in foliage. A broad-leaved form growing only six to eight feet high, is not uncommon in eastern Iowa. The small varieties are said to be more productive of fruit. The small, richly-colored berries, ripe in early summer, are in high favor among some people.

Amelanchier spicata (Lam.) Dec. Low June-berry. Prof. Anderson reports this as occurring on rocky places south. Probably rare.

SAXIFRAGACEÆ.

Ribes cynosbati Linn. Prickly Gooseberry. Occurs sparingly in the wooded parts of the county on the sides of the bluffs, on the hills in Cascade township, etc., known by its very prickly fruit.

Ribes floridum L'Her. Wild Black Currant. Rare. In woodlands, especially in rich alluvial soils. A beautiful shrub, well repaying cultivation by its profuse bloom in early summer. The fruit is good for birds only.

Ribes gracile Mx. Prof. Anderson reports this common in the eastern part of the county.

HAMAMELIDACEÆ.

Hamamelis virginiana Linn. Witch-hazel. Winter-bloom. In Dubuque county, found apparently in the driftless areas only. A bush was noticed in Pine Hollow, and Miss McGee reports it common east of Epworth, which would probably bring it into a similar region. The species is very rare in the state. It occurs in the driftless part of Delaware county, but is not, so far as I can now recall, reported from any other station in Iowa. It occurs rarely along the Mississippi river, opposite Muscatine, but not on the Iowa side. The witch-hazel, long famous in books of medicine, is a favorite ornamental plant wherever known. It is hardy in Iowa, a clean, beautiful shrub. Its curious, showy, yellow flowers coming

so out of season, in October, when all the leaves are falling, are a perennial surprise. The fruit forms during the succeeding summer, so that flowers and ripe fruit may be found on the twigs at the same time.

CORNACEÆ.

Cornus circinata L'Her. Dogwood. Round-leaf Dogwood. A common shrub in all sorts of soil, forming often the margin of the copse, and conspicuous in the season by its cymes of small white flowers. Later on, the light blue berries form a pleasing contrast to the dying foliage.

Cornus stolonifera Michx. Red-osier Dogwood. Not infrequent along streams. Propagated by runners. This species does not thrive well when transplanted to drier localities, but may well take the place of willow here and there, in a low corner of the premises. The flowers are few and small but the pallid or white berries are attractive in the fall, and the red twigs are showy.

Cornus paniculata L'Her. Panicled Cornel-bush. Common along the river banks and by rocky streams. This is the most attractive of our native species, but does not flourish well in our dry uplands. The cymes of flowers are often profuse and panicled, in June, and later on the white fruit is one of the consolations of autumnal woods.

Cosnus alternifolia L. f. Alternate-leaved Cornel. Prof. Anderson reports this frequent.

CAPRIFOLIACEÆ.

Sambucus canadensis Linn. Elderberry. Elder. Common everywhere, the seeds being distributed widely by birds. Sometimes cultivated in farm-gardens for the sake of the abundant fruit.

Sambucus racemosa Linn. Red Elder. Red berried Elder. Miss McGee reports it from the vicinity of Buena Vista. It ranges across the continent but is chiefly north of us in the Mississippi valley. The plant is more woody than the last named and is further distinguished by its brilliant red fruit in

the pyramidal clusters, sometimes *white!* Well worthy of preservation and cultivation.

Viburnum opulus Linn. Cranberry Tree. High Cranberry. Found in the northern part of the county only, along the streams tributary to the Turkey and the Mississippi. This is really the wild phase of our common snowball, and its white flower-clusters show in nature, around the rim, the snowball sterile type. The fruit is bright red and showy, sometimes used instead of cranberries. Certainly a beautiful ornamental shrub.

Viburnum dentatum Linn. Arrow-wood. A small slender tree, not uncommon on low grounds. The fruit is small, purple or dark blue, with grooved seed; otherwise the species resembles the next.

Viburnum lentago Linn. Sheep-berry. Sweet Viburnum. Black Haw. Becoming rare. Formerly common along all streams. A valuable ornamental tree. The white flowers are showy, and the rich black fruit half an inch long is edible.

Viburnum prunifolium Linn. Black Haw. Sheep-berry. Formerly not rare in all eastern Iowa; now almost extinct. Resembles the last species. The fruit is in the two species much the same. The present species is much more common south of us, and is said to be still frequently seen in our southern counties.

Vibarnum pubescens Pursh. Downy-leaved-arrow-wood. Prof. Anderson finds this on the bluffs facing the river.

Lonicera sullivantii Gray. Honeysuckle. Common on rocky bluffs where not too closely pastured. The species is not rare in cultivation and will be useful in covering again the dry rocky cliffs which have been denuded of trees.

Lonicera glauca Hill. Honeysuckle. Resembles the last but occurs more sparingly on rocky hillsides. The flowers are smaller, about a fourth of an inch long, and only the uppermost leaves are connate. Both species are ornamental and useful.

Diervilla trifida Mœnch. Bush-honeysuckle. Not uncommon. Prof. Anderson reports it abundant near Eagle Point.

OLIVACEÆ.

Fraxinus americana Linn. Ash. White Ash. American Ash. Not uncommon in rich and moist woods. One of our finest forest trees, the lumber being of the highest utility wherever lightness and strength are at once desired. The tree is readily propagated from the seed, as hundreds of ash groves in the northwestern part of Iowa abundantly testify. As an ornamental or shade tree the ash is also of the highest rank. Its clean white trunk and dark olivaceous leaves and generally vigorous health make it worthy of our best consideration. It is said that the wood of young trees, second growth, is superior in toughness to the more abundant product of large trees, so that he who plants ash trees may early expect profitable return.

Fraxinus viridis Michx. Swamp Ash. Water Ash. Green Ash. Black Ash. Common on low grounds, especially along the Maquoketa river. A tree of moderate size never attaining the elegance or magnificence of its congener. Nevertheless the green ash is a handsome tree, and valuable alike for shelter and fuel. United States publications write this now *F. lanceolata* Barkh.

THYMELEACEÆ.

Dirca palustris Linn. Leatherwood. Wicopy. Moose-wood. Rare. Once abundant along all the streams of the county. Of no value, save as an ornamental shrub, its exceedingly tough, pliable branches making it an object of curiosity. It presents us, however, with handsome honey-colored flowers in June, followed by oval reddish berries. Refuses to be transplanted and must be raised from seed.

URTICACEÆ.

Ulmus fulva Michx. Slippery Elm. Red Elm. Not uncommon, but less abundant than the following, smaller also and

less valuable. The wood is durable and is said to last well for posts. This is now written *U. pubescens* Walter.

Ulmus americana Linn. Elm. White Elm. American Elm. One of our finest trees and happily common. It affects rich soils, especially bottom lands, and there attains great size and splendor. The large trees in Dubuque county, as elsewhere, have been mostly cut away, but young trees are everywhere. This is our very best street tree. No other species gives us, along the streets and highways, such superb effects. Vigorous health, adaptation to all sorts of soils, enabling it to endure almost unlimited abuse, and general utility combine to make this a most valuable tree.

Ulmus racemosa Thomas. Cork Elm. Hickory Elm. Rare in the northwestern part of the county. Though not so common the rock elm rivals the last in nearly all commendable qualities. The wood is said to be finer grained, tougher, and for some purposes for which elm is used, more desirable; may even take the place of hickory in tool and carriage construction. It is, therefore, in the highest degree worthy our protection and cultivation.

Celtis occidentalis Linn. Hackberry. Not uncommon in low grounds, especially along streams. The trees do not attain large size, but are rapid growers and make excellent fuel. As a shade tree the soft, pale green foliage recommends it in contrast to trees of other species. The red berries are edible, but of small value, save as food for birds.

Platanus occidentalis Linn. Sycamore. Buttonball. Buttonwood. Plane Tree. Rare. Once common along the Maquoketa, between Cascade and Worthington, also along the Mississippi river front. A handsome tree with large leaves and often with snow-white branches. One of the largest of the trees found in the Mississippi valley, sometimes 75–100 feet high and ten or twelve feet in diameter. Does not flourish well on high grounds.

JUGLANDACEÆ.

Juglans cinerea Linn. White Walnut. Butternut. Reported once common by all the streams of the county, now comparatively rare, represented by comparatively small trees. A very valuable species, the wood beautiful for cabinet-work and interior finish. Easily cultivated from the seeds and susceptible of transplanting again and again, when raised in nurseries. Flourishes best in bottom lands and in the neighborhood of streams.

Juglans nigra Linn. Walnut. Black Walnut. Small trees of this species are not uncommon in all the wooded districts of the county. Large trees are said to have been at one time very common. This is one of our finest, most beautiful and in every way most valuable forest trees. It will sound strange to some of our younger farmers when they are told that black walnut trees were once so common in Iowa that they were indiscriminately cut down to make rails to fence the land on which they stood. If standing now such trees would make their owner wealthy. The black walnut, if properly cared for, grows very rapidly. The tree bears fruit in eight or ten years and in as many more will show a trunk twelve to sixteen inches in diameter. In from twenty to forty years under favorable circumstances, good soil, freedom from abuse by cattle, the trees will furnish fine saw-logs. There is many an odd strip of land in Iowa that might be very profitably set to raising walnuts. Better still, there are in our surviving second growth woods, hundreds of young trees which if cared for will reproduce themselves and will in twenty years more be very valuable property. For planting, walnuts should be gathered in autumn, mixed with sand and piled up in heaps, where not subjected to the depredation of thievish animals, to freeze. In spring, plant in rows and cover only an inch or two, and you will have young walnuts to spare. The young trees should be set out when small, unless subject to nursery treatment, when they can be handled safely even when six or eight feet high. The nurseryman transplants early and often

and so modifies the roots. In any event the trees should be planted where they can be cultivated until the ground is shaded, and must be subsequently watched and thinned out as they become large.

Carya alba Nutt. Shell-bark Hickory. Hickory. Common in upland woods. Large trees are rare. Another most valuable tree. The tough white wood is in great demand for carriage building, for construction of agricultural implements, tool-handles, etc.; the waste wood as fuel has long been everywhere famous, the nuts are always salable, while as an ornamental tree it has never been half appreciated. It has the advantage, too, of ability to grow on poor soil. It thrives all over the loess and stony hills of northwest Dubuque county. For cultivation it must be raised from seed—treated as the walnut—as it does not well endure transplanting from the forest. By late writers all hickories are called *Hicoria* Rafinesque, because it is thought that that rather unreliable author intended to apply this or a similar name to the noble group of trees which Nuttall later defined as making up the genus *Carya*. The present species is by these authors written *Hicoria ovata* (Mill.) Britt.,—*ovata* being an early specific name.

Carya amara Nutt. Bitternut. Pig Nut. White Hickory. Common, with about the same range as the last. A small, graceful tree, less valuable by far than the last, but making excellent fuel and well worth a place in our list of ornamental trees. This species by recent authors is written *Hicoria minima* Marsh.) Britt.

CUPULIFERÆ.

Betula papyrifera Marsh. Paper Birch. White Birch. Common on rocky hillsides in the northwest part of the county as in Pine Hollow. A beautiful ornamental tree, its snowy stem shines through the leaves, unique among all the trees of the lawn or hillside. Planted with evergreens for a background, the white stems make a very pleasing contrast in winter.

Betula nigra Linn. Birch. Black Birch. River Birch. Red Birch. Common by the river side, along the Mississippi, and more rarely by the Maquoketa. A small tree of no great value except for fuel. Should, however, have a place among our trees planted for ornament. It has a graceful form, is hardy and healthy, while its glistening leaves and fluttering bark make it very attractive.

Corylus americana Walt. Hazelnut. Common everywhere where not exterminated by processes of cultivation. A valuable bush alike for its fruit and as a nurse for less rugged species—the forerunner of the forest.

Ostrya virginica Willd. Ironwood. Hop Tree. Horn-beam. Common on wooded hillsides. A small, slow-growing tree, the wood very hard and valuable for the manufacture of tool handles and similar utensils.

Carpinus caroliniana Walt. Blue Beech. Water Beech. Not uncommon in little groves or clusters close down at the water's edge along streams everywhere. A small tree, very handsome in its place. The wood useful for the same purposes as the last named species. Both these trees further south attain much greater dimensions.

Quercus alba Linn. White Oak. Common throughout, especially on clay ridges. An invaluable tree. Splendid specimens recently stood in section 5 of Liberty township, just overlooking Pine Hollow, but most of them were cut away a few years since to make lumber for bridges and the like. The oak is of slow growth, but after all will more and more repay protection. It occupies soil of small value for anything else, as in the case mentioned, and in fact soon comes to utility. By judicious thinning of the white oak grove, splendid trees at length stand upon the earth. This is also a beautiful ornamental tree, whether for lawn or park. The clean stem and pale green leaves are very beautiful, while in the autumn the large, handsomely ornate fruit and the leaves glowing beneath the touch of frost, possess a charm that must

make irresistible appeal to every lover of the beautiful in nature.

Quercus macrocarpa Michx. Bur Oak. Scrub Oak. Very common, especially on exposed points, in hard situations, on sandy flats, and rocky knolls. In the last named habitat the tree is apt to be gnarled and stunted, unattractive; hence called scrub oak. The species endures all sorts of adverse conditions, but under these is a tree of very slow growth. Under better circumstances bur oaks come on quite rapidly and make excellent timber. Nothing equals them for posts, and the lumber made from bur oak logs is second to white oak only, in excellent qualities. The tree grows readily from the seed, but is not easily transplanted.

Quercus rubra Linn. Red Oak. Common everywhere in wooded districts. Grows to large size rapidly and furnishes the familiar coarse-grained wood useful to the builder. Some fine specimens are still standing on the clay ridges of the northwest part of the county.

Quercus coccinea Wang. Scarlet Oak. Black Oak. Jack Oak. Common everywhere. A small tree with shining leaves and small fruit, holding its leaves sometimes late into the winter. The most common species in the county as in eastern Iowa. Often occupying almost exclusively a sandy hill entire; especially common in groves remote from the main body of the forest. This seems to be with us a comparatively short-lived tree. All oaks in this country show a certain deterioration with age. The wood of the white oak, for instance is at its best when 75 or 100 years old, and continues at its maximum of excellence for perhaps 100 years longer, probably less; after that the wood deteriorates, becomes brash and in every way less desirable. Trees of the scarlet oak reach a much earlier maturity and seem to die a natural death at 40 to 70 years. Exact data along these lines are much to be desired. *Q. coccinea var. tinctoria* Gray differs in many particulars and is some places more common than the type. It may be known by its generally duller foliage, changing in

autumn to brown or orange, the inner bark orange or yellowish. This is more properly called yellow oak. A better tree than *Q. coccinea.* The variety is now written by some authors *Q. velutina* Lam.

SALICACEÆ.

Salix nigra Marsh. Black Willow. Common along streams and sometimes planted. A small tree of little value save perhaps to form wind-breaks and, by reason of rapid growth, to furnish quick supply of fuel.

Salix discolor Muhl. Pussy Willow. A low shrub along streams, noted for its early flowering.

Salix humilis Marsh. Prairie Willow. On dry uplands. Not very common. A shrubby species of no special value.

Salix tristis Aiton. Dwarf Willow. Gray Willow. Common in thin woods, on the borders of thickets etc., everywhere in poor soils.

Populus tremuloides Michx. American Aspen. Quaking Asp. Common on low grounds throughout the wooded part of the county. With us in Iowa a small tree; further east it attains considerable size, sometimes "100 feet high." Chiefly valuable as a nurse for trees of other species. The seeds are distributed by the wind, germinate quickly and the young plants grow rapidly in exposed situations. For these reasons this tree is of the highest importance in reforestation especially on poor soils, in steep places where it may be used to prevent the washing of the soil, to hold the field until better species get a start.

Populus grandidentata Michx. Poplar. Quaking Asp. Aspen. Common, especially on hillsides in second-growth groves. A slender short-lived tree, noted for rapid growth and useful as a support for trees of other species. The long slender poles are useful to the farmer and are often used as rafters in barns and sheds. The wood is valuable as light or summer fuel.

Populus monilifera Aiton. Cottonwood. Common everywhere and in days gone by commonly planted on the prairie farms and by the highways. Valuable as a shelter tree, also for fuel. In our rich prairie soils it grows with wonderful rapidity; trees thirty or forty years old are sometimes two or three feet in diameter. This, box elder, and soft or white maple are the trees that have made possible the occupation of the prairies of Iowa. This is now written *P. deltoidea* Marsh.

MONOCOTYLEDONES.

LILIACEÆ.

Smilax hispida Muhl. Greenbrier. A common, dark green, prickly vine, sometimes called sarsaparilla. *Smilax rotundifolia*, also occurs. Not uncommon.

GYMNOSPERMÆ.

CONIFERÆ.

Pinus strobus Linn. Pine. White Pine. Rare. A few trees in Pine Hollow, Liberty township. The most valuable tree in the world! There is no lumber for the homes of men that can take the place of pine, and while in other regions other species supplant this, yet none has ever equaled in quantity or wide utility the white pine of northeastern North America. The tree attains great size, and rapidly reproduces itself on soils not destroyed by fire. Second-growth pine, on abandoned farm lands, now furnishes to New England a most important industry. No tree is more handsome on the lawn, no forest better than white pine affords shelter from winter's cold or summer's heat, no trees give in lumber speedier return. White pine grows naturally in our county; it will, under cultivation, prove a thoroughly satisfactory plant.

Juniperus virginiana Linn. Cedar. Red Cedar. Not uncommon along the rocky hills and bluffs. Widely planted as an ornamental tree, for which it is chiefly valuable. It undergoes indefinite clipping and shearing, and makes pretty lawn

hedges. The wood is exceedingly durable, and where it can be obtained in quantity is very serviceable for posts.

Juniperus communis Linn. This is a low shrub, evergreen, with prickly or sharp-pointed leaves; probably occurs in this county. *Taxus canadensis*, American yew, is also to be mentioned here.

It will be seen on reviewing our list that there is hardly a species native to Dubuque county, which does not possess in greater or less degree economic value. These woody plants constitute part of the natural wealth of the county, just as surely as the lead found in the crevices of the rocks. The fact that these particular species flourish here by nature is, as has been already urged, an index to the possibility of forest development, of arboriculture and horticulture, of farm building and home building in eastern Iowa, once science gets a hearing and its teachings reach and influence all the intelligent people that make up our land-owning population. When that time comes Dubuque county will be fairest of our river counties, part and parcel of the most beautiful valley in the civilized world.

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